TECHNICAL EXCISE MANUAL

PREPARED UNDER THE ORDERS OF THE GOVERNMENT OF INDIA

BY

Lieut Colonel C H BEDFORD, D Sc, M D, I M S

Director Central Excise Laboratory for India



CALCUTTA
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PREFACE.

THE present Manual has been prepared for the use of Excise Officers in India during their course of instruction at Distillery Schools, and later on, as a reference book in everyday Excise work

The chapter on gauging has throughout been compiled by Excise Officers, as I have no practical acquaintance with this subject.

The matter for the sixth chapter, dealing with the arrangement of a distillery, has largely been drawn from the official handbooks in use in the United Kingdom

C. H. BEDFORD.

CENTRAL EXCISE LABORATORY FOR INDIA,
Kasauli, 26th September 1910

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TECHNICAL EXCISE MANUAL.

CHAPTER I.

Introductory.

1 *Distinction between foreign and country liquors* —The Indian Excise law makes a sharp, if somewhat artificial, distinction in treatment between foreign and country liquors The former head includes, in addition to all imported liquors, all liquors made in the country in imitation of imported liquors and taxed at the tariff rate This leaves under the category of country liquors fermented liquor prepared according to indigenous processes, plain spirit made from approved bases and taxed at a local Excise rate, and spiced liquors which do not imitate any imported liqueurs or cordials Both foreign and country liquors fall naturally into two classes, according as they are fermented or distilled Fermented liquors are again divided into wines, or fruit liquors, and beers, or malt liquors Distilled liquors are divided into plain spirits, which are the direct product of distillation from an ordinary base, and liqueurs or cordials which are artificially flavoured at some stage of the process of manufacture

2 *Foreign Liquors* —It will be convenient to consider first foreign and then country liquors under these heads

3 *Wines* —Wines are obtained by the fermentation of grapes or other fruits The fruits in question are first pulped and then allowed to ferment naturally That is to say, fermentation is produced by the yeasts naturally present on the skins of the fruit In the [illegible] fermented liquor is strained and casked rea[illegible] the sugar has been fermented are termed [illegible] a relatively large amount of unfermented [illegible] bodied' wines To prevent further fermentation in these, and sometimes to prevent wines turning sour in the tropics, alcohol, usually brandy, is added This is called 'fortification" Wines which contain more than 42 per cent. of proof spirit are not admitted under the tariff as such but are taxed as spirit.

Wines commonly take their names from the places whence they come Thus Médoc is the produce of Médoc in the French Department of Gironde, Sherry comes from Xerez in Spain, and the term Port covers all wine shipped from Oporto, though attempts have been made to confine the term to the produce of the Douro district No wines are made in British India, but small quantities are imported from Kashmir

4 *Cider and Perry*—An exception to the above somewhat arbitrary classification of all fermented fruit liquors as wines occurs in the case of cider and perry which are made from apples and pears respectively, but are treated as malt liquors for Customs and Excise purposes The consumption of these liquors is small Some cider is made in Kashmir, but none in any other part of India

5 *Malt Liquors*—The malt liquors properly so called are beer, ale, stout and porter These are made, where malt and hops are used, by steeping specially prepared or "malted" grain in water, the solid matter is then strained off, this strained liquid is boiled with hops, the hops are next strained off, and the strained liquid is fermented by adding specially prepared yeast After fermentation is over, the liquid is allowed to settle and is then casked for use In modern processes, glucose and other materials are largely used in place of malt, and hop substitutes are occasionally used in place of hops, but the general outlines of the method of manufacture are similar The amount of beer produced in India is nearly equal to that imported The following are the more important varieties which occur —

Pale ale—made from the best malt and with a specially large amount of hops added

Mild ale—stronger in alcohol and extract than the former and with less hops

Porter—a black beer made with specially prepared malt, which gives it its special flavour and colour

Stout—a strong porter

Lager beer—a light beer containing more carbonic acid gas than ordinary beer It is able to contain this extra amount of gas on account of special modes of fermentation carried on at low temperatures by means of special kinds of yeast It is stored at low temperatures

6 *Enumerated spirits*—Of the plain spirits the British tariff distinguishes *between enumerated and unenumerated spirits* Under the first heading are included brandy, rum and Geneva For Indian purposes whiskey may be added to this list All other imported spirits (sweetened or unsweetened) are classified as "unenumerated spirits"

7 *Whiskey*—Whiskey is an alcoholic liquor made by distillation from a fermented mash of cereal grains treated with malt The term must also be held to include for the present at any rate, all spirits prepared so as to possess the distinctive colour, odour and taste of whiskey Scotch Whiskey and Irish Whiskey are whiskeys respectively distilled in Scotland and Ireland

8 *Brandy*—Brandy is, properly speaking a spirit distilled from grape wine, but is held to include any spirit prepared so as to possess the colour,

odour and taste of brandy The French law limits the use of the term "Cognac" solely to brandy made in the Cognac district of France, which includes the Departments of Charente and Charente Inférieure The term "Eau de vie" covers grape spirits from other districts as well as imitation brandies made from other bases In France an official "white certificate" of origin is granted in the case of pure wine brandies Bottled brandies mixed with beet root spirit are required to be labelled 'Eau de vie fantaisie" and are granted an official 'red certificate'

"British Brandy' implies a spirit compounded in England so as to resemble brandy

'Hamburg Brandy' is spirit made in Germany from potato or beet and compounded so as to imitate grape brandy

9 *Rum*—Rum is spirit made from various products of the sugarcane The better qualities are made in Jamaica and Demerara and are known by the names of these localities Imitation rums are made from bases other than sugarcane and are coloured and flavoured so as to resemble genuine rum The law at present does not enforce the distinctive labelling of such spirits, but spirit made or compounded in India for sale as rum under foreign liquor licenses is coloured generally with caramel, before issue

10 *Gin*—*Gin is a colourless spirit sweetened or unsweetened, distilled* from grain or other bases such as barley, rye or maize, and is flavoured with juniper berries or other flavouring agents so as to possess the characteristic taste and odour of gin "Geneva" or "Hollands" is gin imported from Holland *

11 *Unenumerated spirits*—The most common of the unenumerated spirits are spirits of high strengths made from potatoes and other bases and used largely for compounding These are commonly known as "silent" spirits inasmuch as they give no indication of their origin, whereas the enumerated spirits retain a distinctive flavour of the base from which they were originally made Imported rectified spirits are taxed in this category

12 *Colombo arrack*—An exceptional instance of a foreign spirit is the toddy spirit largely imported from Ceylon into the Madras Presidency The locally made toddy spirit in that Presidency has also been declared for the purposes of the law to be 'foreign spirit

13 *Liqueurs, etc*—These are as a rule imported, artificially flavoured spirits They are compounded with a variety of flavouring colouring or sweetening agents The methods of production are usually trade secrets Many British made liqueurs are commonly known as "cordials" "Bitters" are spirits compounded with bitter flavouring agents.

* For a full discussion of what is or is not included in the terms whiskey brandy rum and gin reference should be made to the Report of the Royal Commission on Whiskey and other Potable Spirits (1903) For present purposes the above definitions will be sufficient.

14 *Other imported liquors*.—Other impored liquors with which Excise officers are less intimately concerned are spirits used in drugs, medicines and toilet preparations, denatured spirits, perfumed spirits and medicated wines.

15 *Denatured spirits*.—Denatured spirits are silent spirits which have been rendered effectually and permanently unfit for human consumption under special regulations. They are used only for non-potable purposes such as burning, lighting and in the arts and manufactures. Denatured spirits pay a 7½ per cent. *ad valorem* rate of duty. A minimum strength of 50° O. P. has been fixed for them throughout India.

16 *Perfumed spirits*.—These are scented spirits usually of very high strength. They are taxed on import at an arbitrary rate. Locally made perfumed spirits are taxed at the rate of duty applicable under the tariff to ' spirits—other sorts ', that is, on the silent spirit used in their manufacture.

17 *Medicated spirits*.—Medicated spirits or wines are spirits or wines compounded with various drugs. Their sale is controlled for Excise purposes when they contain more than 20 per cent. of proof spirit. When their strength reaches 42 per cent., they are taxable at the spirit rate.

18 *Country Liquors*.—Under this head there are no wines to consider, though occasionally wines are used in the manufacture of spiced liquor.

19 *Country Beers—Toddy*.—' Toddy ' or "*tari* ' is the most important of the country beers. It consists of the fermented or unfermented sap drawn from any kind of palm tree, from the spadix in the case of cocoanut and palmyra and from the stem in the case of dates. This sap ferments naturally and rapidly. When drawn from the tree, unless the temperature of the air happens to be unfavourably low or unless the collecting pots are clean or coated internally with lime, fermentation starts at once.

20 *Other country beers*.—Other country beers are made from rice, barley or millet, and more rarely from *gur* or *mahua*. Such beers are known in Burma as *u ye* (the first and strongest liquor drawn off) *hlaw-a kaung*, *ka aye seje* and *seinje*, in Bengal as *pachwai*, *handia*, *jaur*, *marua*, *kusna* and *sugla*, in Eastern Bengal and Assam as *bo a*, *malh zu* and *laopani*, in the United Provinces as *bora*, *darbalra*, *soma* and *rabra*, in the Punjab as *sur*, *lugri* and *chang*, in Madras as *londa*, *herda* and *sonti soru*, in Mysore as *alli bhoja*, in Kashmir as *chang* or *arak*.

Pachwai is made from husked rice which is boiled or pulped. A special fermenting agent is then mixed with it and when fermentation is completed the liquor is strained off and drunk diluted or undiluted.

21 *Country spirit*—Country spirit is plain spirit made from materials recognised as a country spirit base It is issued and sold, generally at fixed strengths and at country spirit shops subject to the local rate of Excise duty The fermentative bases ordinarily recognised are (1) more or less crude or unrefined sugar, *e g* cane or date *gur*, jaggery, molasses or *shira* (2) *mahua* which is the dried flower of the *Bassia latifolia* tree, (3) in special cases toddy, raisins dates etc

22 *Rectified spirit*—Rectified spirit made in India is ordinarily subject to the same regulations and duty (Rs 11-4 0 per proof gallon) as similar spirit imported from abroad

23 *Spiced spirit*—The only flavoured liquors now recognised as country spirits are the spiced spirits made in the Punjab, Sind and Bombay and to a small extent in Ajmer Merwara and Baluchistan The flavouring agents are usually added between the first and second distillations and are selected from among the following —aniseed cardamom, coriandar, ginger, orange, *mundi* (*Sphæranthus indica*), *nim*, peppermint, mango, jasmine (motia) *khas khas* (*Andropogon muriaticus*) sweetlemon, rose, etc

24 *Proof strength*—It remains to explain how the strength of spirit is reckoned for duty purposes *In the assessment of duty on spirit and in com*mercial transactions relating thereto the standard of strength is termed "proof" This is the scale to which Sikes's hydrometer has reference. The term "proof" comes from the method formerly used by the Excise in testing a spirit s strength by pouring a certain amount of it on gunpowder and then applying a light *If the spirit was over "proof" strength, the gunpowder* ultimately took fire, if it was under "proof" strength, the gunpowder was too much moistened by the water in the spirit to do so Different countries, such as America and Holland have different standards of proof The standard in use in India is the English standard commonly known as "London proof" *London proof spirit is defined by Act 58, Geo 3,* c 28, as a mixture of alcohol and water "such as shall at a temperature of 51° F. weigh exactly 12/13th part of an equal measure of distilled water". In other words 13 volumes of proof spirit shall weigh the same as 12 volumes of water at that temperature The "proof" spirit thus defined has a density of 91981 at 60° F and contains 49 24 per cent by weight of alcohol and 50 76 per cent of water, or 57 06 per cent of alcohol by measure* or volume Spirits weaker than this are described as so many degrees or so much per cent under proof (U P) Thus spirit of 20 per cent under proof (20° U P) contains at 60° F 80 measures of proof spirit and

20 of water Pure water is 100° under proof 50° U P. spirit contains equal measures of proof spirit and water

Over proof (O P) spirits are those stronger than proof spirit and are described according to the number of measures of proof spirit that 100 volumes would yield when suitably diluted with water Absolutely pure alcohol is 75¼ degrees O P and contains 175¼ per cent of proof spirit, so that 100 volumes when diluted with water yield 175¼ volumes of spirit at proof

25 *Rectified spirits of wine*—This is the name given to the most concentrated alcohol obtainable by ordinary distillation It is silent spirit which should be of not less than 50° O P. strength Spirit up to 70° O P (97 per cent by volume) can be produced, but ordinarily 68° O P is the upper limit of strength producible in patent stills on a commercial scale,—the average strength, in the United Kingdom, being about 66° O P Spirit of this last strength is also produced in India Rectified spirit of the British Pharmacopœia is made by a special process and contains 90 per cent of alcohol by volume The legal limit in England as imposed by section 39 of the Spirits Act, 1880, is 43° O P A more convenient limit for India would be 50° O P. which has been adopted as the minimum limit of strength in the case of denatured spirit

26 *Absolute alcohol* —Absolute alcohol is obtained from rectified spirit by removing the water present as much as possible by treatment with quicklime or potassium carbonate The term absolute alcohol is a relative one Commercially, the name is given to any spirit stronger than can be produced by distillation alone The absolute alcohol of the British Pharmacopœia should not contain more than one per cent by weight of water, and has a density at 60° F of from 0 794 to 0 7969 These densities are equivalent, respectively to 99 95 and 99 4 per cent of alcohol by volume * It may be noted here that absolute alcohol tends to absorb water rapidly from the air when exposed for even a short time

27 *Average alcoholic strengths of Liquors*—The average *volume percentage* of alcohol in various liquors is as follows —Whiskey, Brandy and Rum, 50, Gin, 43 , the lighter wines such as Claret, Burgundy, Rhine wines, Champagnes and Moselles, 10 to 15 , the stronger wines such as Port, Sherry, Madeira, 15 to 25 , Vermouth, 17 to 20 , Kummel (Russian), 43

Beers Pale ale and light bitter ale, 6 to 7 , Indian made pale ale, 5 to 8 , Pilsener, 5 to 6 , Black Munich beer, 5 , Porter, 5 to 6 , stout 7 to 8 , old ale 13 to 14 , the native or "tavern" ale of the Nilgiris and Bangalore, 8 to 11

Pachuai · strong, 15 to 20 , diluted, 5

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* British Pharmacopœia 1898

Toddy Date and Palmyra, 4 to 5, Cocoanut, 8, Sago, 6

Medicated Wines Vibrona, Peptone Wine, and Wine of Cod Liver Oil 19 to 20, Wincarnis Aswagandha Wine and Coca Wine, 16 to 18

28 *Legal limits for spirit strengths* —Under the English Food and Drugs' Act Amendment Act of 1879, minimum strengths have been fixed of 25° U P for whiskey, rum and brandy, and 35° U P for gin The same limits have been adopted in most provinces in India both as regards imported and locally made "foreign" spirit, but specially high priced spirits have been exempted In the case of country spirits fixed issue and sale strengths are now generally adopted Those most commonly in force are 25° U P and 60° U P, but 15°, 20°, 30°, 40°, 45° and 50° U P have been adopted in some cases In Bengal liquor weaker than 60° U P is also issued

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CHAPTER II.

Materials.

29 *Sugars and allied substances* —Sugars and allied bodies capable of forming alcohol by fermentation are compounds of the elements carbon, hydrogen and oxygen They contain hydrogen and oxygen in the proportions necessary to form water *i e*, twice as much hydrogen as oxygen Thus dextrose in addition to its carbon, has twelve proportions* of hydrogen and six of oxygen, and is hence able to form six proportions of water, which consists of two proportions of hydrogen and one of oxygen Bodies of this nature are chemically termed carbohydrates, or hydrates of carbon Starch, cellulose gum and dextrin are other examples of carbohydrates Carbohydrates may, for the present purpose, be divided into two kinds fermentable and unfermentable The sugars may be divided into simple sugars (like glucose or grape sugar), which can be directly fermented, and sucroses, more complex sugars like cane sugar, which cannot be directly fermented but require to pass through a simple preliminary stage, called inversion The allied substances like starch, which is the main constituent of cereal grains such as barley and rice also require to pass through a preliminary process called "saccharification" or conversion into sugar, before they can directly ferment under the action of yeast One proof that a substance is a sugar is that it can be fermented into alcohol and carbonic acid gas, and this process is termed vinous or alcoholic fermentation During fermentation only about

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* The term proportion is used in order to avoid consideration of "atoms" and molecules

4 or 5 per cent of the sugar becomes convertible into the substances (other than alcohol and carbonic acid gas) which are termed by products.

The yeast takes up about 1 to 1½ per cent of the sugar elements during fermentation No methyl alcohol or "wood spirit" is formed during vinous fermentation

30 *The process of inversion* —Cane sugar does not ferment directly as does glucose It requires first to be changed into a mixture of the ferment able sugars known as dextrose and levulose The mixture of dextrose and levulose resulting from inversion is an uncrystallisable syrup which has a sweeter taste even than cane sugar and is called invert sugar, or, com mercially, "invert"

Dextrose occurs in sweet fruits and grape juice, along with cane sugar and levulose It is also found in honey and many kinds of cereals When starch is boiled with dilute acids, water is taken up and the starch splits up into dextrose and dextrin

Levulose occurs in the invert sugar of honey and certain fruits, probably always along with other forms of sugar It is chiefly obtained by inversion of cane sugar by the aid of yeast or dilute acids, or by a special ferment

Inversion is caused either (1) by the presence of a body in yeast called invertin or (2) by the action of dilute acids such as hydrochloric or sulphuric This change (inversion) is brought about by the cane sugar taking up a definite proportion of water Inversion occurs at ordinary air temperatures, but is hastened by heating

31 *Conversion* —"Conversion" of starch into sugar is similarly produced by another substance present in yeast called diastase, or by the action of acids under artificially increased pressure and heat The starch of rice is also convertible into sugar by certain moulds which grow naturally on the damp rice In certain parts of India and China, these moulds are collected and used like brewer s yeast

Bakhar is such an agent mixed with other vegetable substances and caked
In China, Japan, Assam, Burma, etc, such moulds are prepared or imported
in small cubes or balls These produce an alcoholic liquor from rice which may contain over 20 per cent of alcohol, whereas in ordinary vinous fer mentation the yeast only yields about 15 per cent (by volume) at most Ordinary distillery washes range up to 10 per cent (by volume) or slightly over, but in India they often reach a much less amount

32 *Caramel Production* —When sugars like dextrose which contain the elements of water are heated sufficiently, the water is driven off and a number of bodies of indefinite composition are produced and these are known as caramel and its derivatives Caramel, or "burnt sugar" is thus not one substance but a mixture of several It is used for colouring and flavouring purposes The best method of preparing it is described in Chapter XI

33 *Materials commonly used in Europe*—Whiskey may be made from malted barley or mixtures of the same with various cereals such as unmalted barley, maize, oats, rye and wheat In Scotland, pot still whiskey is generally only made from barley malt In Ireland, a mixture of barley malt and unmalted barley, oats, wheat and rye is employed, and usually four fifths of the whole mash consists of barley (malted and unmalted) and the remaining one fifth of a mixture of oats, wheat and rye

For whiskey made in a patent still the bases used in England are chiefly maize and molasses with some malt In Scotland and Ireland, maize, rice barley, rye and oats with malt in varying proportions, according to the particular flavour required are employed In Germany, Belgium and France, beets and potatoes are largely used For making spirit for denaturation, molasses is chiefly used in England

Brandy—Genuine brandy is made from fermented grape juice which is then distilled to separate the spirit and its volatile flavouring agents from the other constituents

The term '*Eau de vie*' is legally applicable to spirit made from wine, cider perry grape skins (left after wine making), cherries, plums and other fruits and also to a mixture of such *Eau de vie* with plain spirit made from grain, potato or beet root

The best French brandies come from the Cognac region, and are termed Cognac

Rum—Genuine Rum should be entirely made from sugarcane products But the term ' rum is also conceded to what should properly be called "Imitation Rum", made from bases other than sugarcane and having the colour and flavour of rum

Gin is a grain spirit made from cereals, chiefly maize, malt and rye It should be flavoured by redistillation with juniper berries Imitation gins are plain spirits flavoured with genuine gin or more commonly with flavouring essences so as to taste like gin

34 *Materials used in India*—The bases in use in India have already been enumerated in Chapter I, but some further details as to them may now be given

35 *Mahua*—That which is perhaps the most important of them *mahua*, *mohwa* or *mhowra* is a base peculiar to India The sugary flowers which fall, or are collected from the tree known as *Bassia latifolia* are used for making *mahua spirit* and to a very small extent, *mahua* fermented liquor The tree occurs in the central regions of India "from Western Bengal, Oudh and Kumaon to Gujerat, Kanara and Burma It ascends the hills to altitudes of close on 4 000 feet and is often cultivated *Bassia longifolia* is another variety which occurs from the Konkan southwards and replace *Bassia latifolia* in

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South India*" The flowers of this tree are not used for spirit making The *mahua* flowers are cream coloured and occur in large clusters The tree flowers from February to April About March the flowers mature, and continue, till the end of April, to fall to the ground Each tree yields from 2 to 4 maunds of flowers The fall of flowers is generally complete in about 10 days The collected flowers are dried in the sun and turn reddish brown and have a rather mouse like odour The flowers collected for sale are not allowed to dry as much as those kept for food When kept for some time, they are liable to become black coloured and of a moist appearance, denoting partial fermentation Such contain less sugar than the fresher flowers

36 *Sugar*—Sugars made in India may be classified as follows — (1) Cane juice (*ras*), (2) Refuse of bruised canes (*megass*) which is termed *pata* (3) the raw sugar, which is *jaggri* or jaggery, also *gur* or *gul* (4) *Rab* is the juice which has not been boiled down so much as *gur* and which is sold in a more liquid condition, (5) molasses and treacle are the uncrystallis able sugars drained away from *gur* and *rab* (molasses is known as *choa, bhira, lapta math*, and treacle as *putri lat,* etc), (6) Country sugar is a higher grade article than (3) and one which has been longer boiled than *gur* and which on cooling has been stirred till it thickens It is not refined and is termed *lal shakar, khanr, bhura choyanda,* etc (7) Refined or white sugar is made from *rab* by boiling and clarifying and then the scum (called *shira*) is removed and finally the sugar is drained of its molasses This is *putri*, or, if further washed and crystallised, it is termed *khand* There are various qualities of crystallised sugar or *khand* From *khand* are made the white crystalline sugars termed *misri* and *chini* *Kuza khand* corresponds to English sugarcandy

Sugar spirits are made from cane or date *gur* or *shira* (either alone or *mixed with mahua*), *cane or date chitta (treacle), molasses jaggery (cane* and palm), etc, the uncrystallisable residues being generally preferred Country vinegar is often made from *shira* and *pata* †

37 *Other bases*—Spirit made from *mahua* or sugar bases forms by far the larger proportion of that consumed in India at the present day, but a variety of others have been, or are still, used either licitly or illicitly The most important of these is toddy, which at one time formed the base of a large proportion of the spirit drunk in the Bombay and Madras Presidencies This spirit has now been declared, in Madras, to be taxable at the tariff rate Grain spirits have been made from rice, barley, wheat, millet and *marua* or *ragi* (*Eleusine coracana*) Rice spirit was at one time extensively manu factured in Bengal The use of this base is in some provinces discouraged as involving a waste of food stuff and also because the illicit manufacture of rice spirit is not uncommon and it is desirable that the licit should be easily distinguishable from the illicit article The only other grain spirit of import-

* Watt's Commercial Products of India edition 1908 pages 116 7

† Watt's Commercial Products of India edition 1908 page 952

ance is whiskey made from malted barley in the Punjab for European consumption Fruits used are raisins and dates in Sind, dried apples and pears in Kashmir, and, very rarely, pine apples and prickly pear A peculiar liquor is made in Goa from cashew (*Anacardium occidentale*) This is popularly believed to have diuretic and sweat producing (diaphoretic) properties, and to be useful when applied externally in cases of rheumatism Analysis shows that it contains, though in very small proportions, the active principles of the cashew (*ur*, cardol, which has irritant properties, and anacardic acid, which is an active drug) It is not desirable that the spirit should be used for ordinary consumption In the Bombay Presidency its import is prohibited

38 *Permissible and inadmissible additions* to *liquors*—Acacia bark is a legitimate addition to the wash The fruit of *Phyllanthus Emblica* known as *amla, aonla, amlaki, daula*, or *gondhona*, is a harmless addition to the wash but permission to add it should always first be obtained from the Excise Department

The use of such substances as the following at any stage should be strictly forbidden —

> *Dhatura*, Indian hemp, *Strychnia* or *Nux Vomica* seeds, Opium or poppy capsules, aconite colocynth (bitter apple or *tuh*), *Terminalia bellerica* (*bhaira, sagona*) or *Terminalia chebula* fruits (*harra, hilikha*), *Sorghum vulgare* (*juar*) root, *Gomyin* seeds (*Entada scandens*) and tobacco

39 *Spirit yields*—The following table which is based on results obtained at the Central Excise Laboratory Kasauli shows the amounts of fermentable sugars ordinarily present in *mahua, gur, shira*, and *jaggeri* —

Bases.	Total sugars present			Invert sugars •	Cane sugar	Possible theoretical yield per maund in proof gallons.	Possible yield in proof gallons
	Maximum	Minimum	Average				
	Per cent	Per cent	Per cent	Per cent	Per cent		
Mahua •	6 0	52 8†	6° 0	4°½ to 55	2 to 15	6 0	5 0
Gur	°1 5	55 0	64 3	6 8 to 1° 5 average 10·2	44 to 61 5 average 54 4	6 4	5 4
Shira	6° 5	4° 1	53 1	3 3 to 18 °5 average 14 8	24 35 to 59 2 average 35 3	4 8	4 1
Jaggery	94·0	°0 8	83	2 to 18 5 average 10·11	65 to 85 9 average 36	° 4	6 3

• When *mahua* solutions are examined by the polariscope they usually appear to be inactive as the levulose present balances the dextrose It may also be noted that in *mahua* the soluble solids not sugar average 11 5 the insoluble matter 15, and the moisture, 16 *per cent*

† Old *mahua* samples may contain as little as 35%

Other bases used give, with skilful working, the following yields —

220 lbs Wheat	yield 7 0 gallons alcohol	
Rice	7 7	,
, Rye	6 1	,
, Barley	5 5	,
, Oats	4 8	,
Indian corn	5 5	,

Wheat gives a malt as rich as barley in some respects, but is scarcely ever used in India Rice, oats, Indian corn and rye have so much value as foods that they are comparatively rarely used unless damaged

Sweet cassava root is also occasionally used A ton of root (containing 23 per cent of starch) should yield about 38 gallons of alcohol at 90 per cent by volume

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CHAPTER III.

Fermentation and the Use of the Saccharometer.

40 *Setting up the wash* —Five agents are needed to produce alcoholic fermentation —

(1) Sugar, (2) Water, (3) Ferment, (4) Heat, and (5) Air In the absence of any of these fermentation cannot proceed

In spirit manufacture by European methods the material used, called the fermentative base, is, after inversion or conversion, if these are required, steeped in hot water to extract the sugary matter The resulting solution of sugars is termed the wort To this wort, when cooled to a particular temperature, the ferment yeast is added in order to start fermentation This is termed "setting" or "pitching" the wort The yeast should have been grown under such conditions that it consists entirely of pure yeast In the presence of pure vigorous yeast, other germs (wild yeasts, acid forming germs) tend to die The Indian distiller, however, and occasionally the European distiller in India also does not add a special yeast to his fermentative material chiefly because a supply of pure yeast is usually not available Moreover, some yeast is naturally present in his fermentative bases and the temperature employed in extracting the sugars is not high enough to kill this yeast On the surface of *mahua* flowers, *gur*, etc, certain yeasts are to be found and these start fermentation as soon as the sugars pass into solution For this reason the sugary solution rarely exists as a true wort, which is properly an unfermented liquid but becomes almost at once technically a wash, that is to say, a fermenting or fermented liquid Thus the term wash has for convenience been adopted herein for all distillery liquids before distillation A process somewhat analogous to "pitching the wort" in European distilleries exists in some Indian distilleries in which a proportion of what is termed "active wash" is added to the wash as is described in a later paragraph

41 *Methods of dealing with the solid matter in mahua washes* —The pitching of washes made from sugar bases which can readily be dissolved, presents no difficulty The conditions under which *mahua* washes can best be fermented have not yet been properly worked out The common indigenous process is simply to mix the *mahua* with spent wash and water, to depend on natural fermentation and to pass the whole wash when fermented including the solid matter, into the still This is a process that results both in waste of materials and in the production of an inferior spirit, as will be shown later Several attempts have been made by breaking up the *mahua* to produce a wash similar to that made from potatoes but so far no satisfactory process has been evolved More success has attended experiments with the diffusion process In this it is usual though not absolutely necessary, to place the *mahua* first in a covered raised tank, preferably with a conical foot to add sufficient water and then to turn on hot water (or steam through a number of jets) so as to ensure thorough mixture When a considerable part of the sugar has been dissolved in this way the mixture is distributed over a series, or battery, of wooden vats with perforated false bottoms In these the *mahua* is further macerated by hot water passed through the battery being kept hot by a coil of steam pipes meanwhile By this means practically all the sugar is dissolved out in six or eight hours and the wort is ready to be poured into a fermenting vat the *mahua* being removed through the hitherto closed false bottoms of the maceration vats It will be observed that if steam or boiling water has been used a wash so prepared contains no live yeasts and that these must be added in the form of active wash or as a specially prepared yeast before it will ferment

42 *Proportion of water to materials and dilution of wash* —It is important not to use too strong a sugar solution The chief reason for this is that alcoholic fermentation cannot proceed in a wash that contains more than a certain percentage generally 10 per cent of its bulk of alcohol, so that any sugars that remain in the liquor after this point has been reached are wasted It has long been known that with less than four parts of water to one of sugar fermentation takes place imperfectly or not at all There is a tendency in India to use less water than this proportion which results in waste especially in the case of a base like *mahua* which requires a large amount of water to extract the sugar from it In Europe where the amount of sugar extractable from any base is well known or carefully found by experiment beforehand the actual proportion used is most carefully regulated by the help of an instrument called a saccharometer and if too much sugar is present in the wort water is added in order to dilute to the necessary degree. The saccharometer is fully described later in this Chapter In any comparison of yields the number of pounds per maund should be stated as the maund varies in different Provinces

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43 *Original gravity*—The density or gravity noted when the wort or wash is first prepared is known as the first or original gravity to distinguish

it from the lower gravities found as fermentation proceeds, that is, as the sugar which is heavier than water, is changed into alcohol, which is lighter than water

With some Indian fermentative bases, the first gravity does not entirely represent sugars or other fermentable substances and further experimental work is required to ascertain what proportion represents non fermentable materials in solution It is known however, that the first or original gravity in Indian distilleries not under skilled management is frequently too high For patent Stills the most suitable original gravity is 1045°-1050° whilst for pot still a somewhat higher original gravity should be employed as being more economical Different qualities of *mahua* or of *gur*, etc , yield different quantities of sugars in solution so that it is impossible to direct that so many gallons of water shall be added to so many maunds of the fermentative base as the resulting gravity will vary with the quality of the base employed Consequently it can only be laid down, firstly, that the most suitable initial gravity for the different kinds of bases under different conditions should first be determined , and secondly, that it should be ascertained by the use of a saccharometer that this gravity has been attained before any fermenting agent is added to the wash

44 *Yeast and the use of active wash*—The culture and preservation of yeasts suitable to different washes is a study in itself and one with which little progress has been made in India It is not proposed therefore to discuss here the experiments that have been made It may be safely said, however that experiments with brewer's yeast for *mahua* washes have not been generally successful and that a cheap and satisfactory yeast for the fermentation of *mahua washes* has yet to be discovered The smaller Indian distilleries depend entirely on the wild yeasts present on the *mahua* The more advanced improve on this somewhat by adding to the wash when set up either a portion of an already fermenting wash from another vessel or a portion of a specially prepared fermentation In either case the yeast is impure and the consequence is that, although the distiller may have every other requisite for proper fermentation, he can never control the process in an exact manner As a result the wash becomes contaminated in many cases to a disadvantageous extent by acid producing germs which tend not only to make the liquor sour, but to stop fermentation before all the sugar in the wash has been converted into alcohol The acid so produced is distilled over to an undesirable extent along with the alcohol and, if the spirit is weak, the acid in it tends to make it increasingly sour Such spirits keep and carry badly

45 *Use of "spent wash" in subsequent fermentation*—The wash in many distilleries when set up is mixed with a proportion of spent wash This must not be confused with the proportion of "active" wash added

in order to help to set up fermentation The effect of adding the spent wash is to restrain the growth of acid forming germs and to act as a yeast food If added when still boiling to the dry *mahua* it may have the effect of sterilizing the wash Spent wash contains some phosphates and nitrogenous matter which are good yeast foods It also contains lactic and other organic acids which within certain limits help to make the yeast more vigorous and also to check the growth of acid producing germs Mineral acids, such as sulphuric acid, do not act so well as organic acids for this purpose The Indian distiller acts empirically in this matter of adding spent wash, probably from previous observation or custom, which shows it to be a useful plan in practice One risk of this haphazard method is that wild yeasts of undesirable type get into the wash and stop fermentation before all the sugars have been used up and these wild yeasts also tend to produce deleterious substances which distil over with the alcohol

Any change in such matters is likely to be very slow in India But the continuance of the present crude methods means wasteful and dangerous manufacture, which cannot be efficiently controlled by the Excise or by the distiller

16 *Other additions to the wash*—Such substances as Ammonium Sulphate and Sulphuric Acid are occasionally added to the wash with the view of quickening fermentation Ammonium Sulphate is added as a nitrogen containing food for the yeast Sulphuric Acid is added to restrain the undue production of acid forming germs such as the acetic and lactic ferments and by so doing to lessen interference with the yeast's action Both these methods tend to quicken the course of healthy fermentation and are used in certain of the larger distilleries with satisfactory results The bark of the Acacia tree, known as babul or *velam* (probably an abbreviation of the Tamil *kurruvelam*), is largely used in sugar washes in the Madras and Bombay Presidencies and elsewhere Its action is due to the tannic acid it contains, which acts by precipitating albuminous matter from the wash, thus facilitating fermentation It also tends to check excessive acid formation in the wash Other species of acacia as well as the above mentioned *Acacia arabica* are used for the same purpose *Imla* is used for a similar purpose in Central India and elsewhere This is the astringent fruit of *Phyllanthus Emblica* Its action is due to its tannic acid *Carbolic acid* has occasionally been used to restrain the growth of acid organisms in the wash or to clean out fermenting vats after use It should never be used for any such purposes as it spoils the smell and taste of the liquor and if used in sufficient quantities may cause actual symptoms of poisoning

17 *Salts which aid or check fermentation*—Certain salts when present help fermentation, for example, sulphates of sodium, potassium ammonium,

calcium (lime), zinc, copper or aluminium, chlorides of sodium or potassium, calcium or ammonium, tartrate of potassium, lactate of sodium

Fermentation is hindered by—

Sulphates of iron and manganese, nitrates of potassium and ammonium, etc

48 *Examples of well proportioned washes*—An excellent example of a well proportioned molasses wash is as follows —

50 per cent palmyra and cane runnings, 25 per cent of cane treacle 25 per cent of palmyra treacle Water is added till the density is 1050° Then to each 3,000 gallons of wash, 4 lbs of brewer's yeast, 75 lbs of acacia bark, 5 lbs of ammonium sulphate and 40 ounces of sulphuric acid are added

As an example of the proportions used elsewhere, the following wash may be taken —

65 Bengal maunds of *mahua*, 100 gallons of spent wash, 1,800 gallons of water, 8 drachms of commercial sulphuric acid, and ½ pound of ammonium sulphate

49 *Aeration of the wash*—Air is particularly necessary at the beginning of fermentation Certain distillers hold that after fermentation has been freely started, the vat should be covered and the layer of carbonic acid gas resting on the liquor's surface should not be disturbed, adding that, if it is, acid fermentation results and that this is especially apt to occur towards the end of fermentation But it is certain that excellent results are obtained by the use of vats uncovered during fermentation It is a good plan, however, to cover the vat towards the end of fermentation in order to lessen evaporation of alcohol and risk of over-acidity To keep the true yeast healthy, especially if the original supply is small, it may be necessary to further aerate the wash by stirring it Yeast requires a certain amount of oxygen for its existence and more especially for development and growth In some modern distilleries, where the manufacture of yeast as an article of commerce is conducted simultaneously with manufacture of alcohol, a gentle stream of air is continuously pumped in during fermentation Fermentation under Indian conditions usually slows down because the yeast employed is weak in character and small in quantity, and aeration is necessary in these cases Stirring also more effectually brings unfermented portions of the wash into contact with the healthy yeast cells

50 *Stirring the wash, and frothing*—Stirring should never be effected by thrusting the arm into a fermenting cask or small vat, as is often done in Indian distilleries A wooden pole with a broadened end should be used If marked frothing of the wash occurs, stirring is inadvisable Frothing over is best avoided by the use of sufficiently deep vats The loss from froth-

ing can often be kept within fair limits by beating down the froth without stirring up the wash, with flat pieces of wood Besides the loss, the contamination of the fermenting room floor is to be strictly guarded against Froth which has been allowed to overflow from such a fermentation will often prove a source of frothing in later fermentations

51 *Means of regulating the temperature of the wash* —The temperature of the wash must not rise too high or fall too low, as in the first case improper fermentation results and in the second case fermentation is arrested The lowest point at which fermentation can proceed is 59° Fahr, and about 82° Fahr is the most favourable temperature for vigorous fermentation This regulation of temperature can most readily be effected by placing a coil of metal tubing in the wash and then passing through the coil a current of cold or of hot water as may be required Such a coil is termed an "attemperator" Evaporation from the outside of the earthen pots used in crude Indian distilleries acts to some extent as a means of cooling the wash, but in such cases no regulation of temperature is possible and the high air temperatures, though promoting evaporation when the air is dry, in many places reduce the cooling effect to negligible dimensions

The effects of a temperature higher than 82° Fahr are—

(*a*) Increased production of fusel oil and ethers,

(*b*) Lessening of the activty of the yeast,

(*c*) Greater tendency to help the growth in the wash of harmful germs, such as those producing acetic lactic and butyric acids, which stop the action of the yeasts and hence lessen the production of alcohol The later stages of alcoholic fermentation are the most dangerous as regards excessive acid production Different yeasts differ considerably in their sensitiveness to acetic acid, but most yeasts power of working is hindered or stopped by its presence in a proportion of one per cent One half per cent of lactic acid or even $\frac{1}{10}$th per cent of butyric acid seriously interferes with the yeast's action, while fermentation stops when the ethylic alcohol present in the wash amounts to 15 per cent the amylic alcohol to 1 per cent, the butylic alcohol to 2 5 per cent, or the propylic to 10 per cent The average amount of ethylic alcohol in spirit washes in India may be taken as about 10 per cent

52 *Time to be allowed for fermentation* —The proper length of fermentation depends on many conditions such as the quantity of wash, temperature, activity and purity of the yeast, quality of the fermentative bases used etc Much thus turns on the skill and care of the distiller and the use of appropriate

plant and materials The times allowed by various distillers throughout India in 1905 06 were ascertained to be as follows —

Base used	Hot weather	Cold weather
Madras—		
Jaggri or molasses	28—32 hours	32—36 hours *
Do	6—8 days	7—9 days
Treacle and cane runnings	36—40 hours	40—48 hours*
Jaggri	10—14 days	12—16 days
Do	6—8	13—14
Do	6	8
Bombay—		
Mahua jaggri raisins	5—6	7—10
Mahua	6—8	8—10
Do	6 7	7—8
Do	4	5
Do	5	8
Do	3—4	5—6
Molasses	4—5	6—7
Toddy	2—3	3—5
Do	3	5
Bengal and Eastern Bengal—		
Mahua and molasses	6—7	10—12
Do	4—6	6—8
Mahua and *gur*	3—5	6—8
Do	4—5	5—7
Do	4—5	6—7
Mahuo	3—5	6—10
Do	5—7	7—9
Do	4—6	6—10
Do	3—4	6—7
Cane *gur*	13—17	17—22
Do	9—10	13—15
Do	19	21
Date and cane molasses	9	12
Date *gur*	7—10	10—15
Date		12
United Provinces—		
Mahua and *shira*	3—5 days	up to 9
Mahua	3—5	up to 9
Shira		up to 4 *
Punjab—		
Molasses	4 days	5
Gur or *khand rab* (Hill distillery)	3—4	6—7 *
Gur	3—6	6—7 *
Gur	60 hours	72 hours*

* The distilleries at which these periods were allowed are under European management

The great variations according to climate season of year quality of materials used care and skill of distiller are sufficiently indicated in the above statement Some of the longest fermentations met with are those in which *jaggri* or *gur* have been used but on the other hand the most rapid fermentation among the examples given was one of *jaggri* or molasses A badly

conducted *jaggri* fermentation may last a fortnight, which is, of course, a very objectionable condition of affairs from the point of view of economy of working and the quality of the resulting liquor The crude toddy fermentations run their course in 2 to 3 days in summer and in 3 to 5 days in winter, so that toddy is by far the most quickly and easily fermented of the bases used in Indian distilleries, though in other respects an undesirable base in practice *Mahua* is ordinarily a slow base to ferment, but this, again, is a result of the crudity of the process generally employed

53 *Methods of determining when the wash is ready*—Indian distillers frequently decide when the wash should be removed for distillation merely by its alcoholic odour, sound of bubbling or the non appearance of gas bubbles on its surface Some pass the wash to the still after a fixed period without reference to its actual condition The rough tests mentioned are misleading, as a powerful alcoholic odour only proves loss of alcohol by evaporation, whilst gas bubbles may and do emerge long after true vinous fermentation is complete The avoidance of an over prolonged fermentation is a most important matter The alcohol in a wash goes on collecting until a point is reached at which it is present in sufficient amount to check any further action of the yeast From this point onwards, fermentation dies away and the active bubbling of the liquid ceases Entangled gas bubbles, however, may escape for days afterwards so that an instrument which shows when alcohol is no longer being formed has to be employed A daily examination of the fermenting wash by testing the gravity with the saccharometer is thus of the highest importance to decide when alcoholic fermentation is really complete (as is further explained in the succeeding section) The proper way of determining whether fermentation is complete is by (1) observing the temperature by means of a thermometer, and (2) seeing whether the specific gravity of the wash is stationary or not by means of a saccharometer At the commencement of fermentation, the temperature begins to rise on account of the heat produced by the chemical changes occurring, it attains a maximum, or highest point, and then falls to a stationary point The specific gravity steadily falls as fermentation proceeds, as the heavier sugar is turned into the lighter alcohol and gas When the specific gravity is at a stationary point, fermentation is complete

Example.—

Stage of fermentation	Specific gravity	Alcohol volume percentage	Acidity percentage	Temperature, Fahr
On setting up fermentation	1100 6	0 4	0 36	70°
1 day later	1056 7	6 4	0 51	80°
2 days later	1028 9	9 4	0 81	75°
3 "	1024 8	9 7	1 0	70°
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4 „ „	1024 8	9 6	1 0	70

conducted *jaggri* fermentation may last a fortnight, which is, of course, a very objectionable condition of affairs from the point of view of economy of working and the quality of the resulting liquor The crude toddy fermentations run their course in 2 to 3 days in summer and in 3 to 5 days in winter, so that toddy is by far the most quickly and easily fermented of the bases used in Indian distilleries though in other respects an undesirable base in practice *Mahua* is ordinarily a slow base to ferment, but this, again, is a result of the crudity of the process generally employed

53 *Methods of determining when the wash is ready*—Indian distillers frequently decide when the wash should be removed for distillation merely by its alcoholic odour, sound of bubbling or the non appearance of gas bubbles on its surface Some pass the wash to the still after a fixed period without reference to its actual condition The rough tests mentioned are misleading, as a powerful alcoholic odour only proves loss of alcohol by evaporation, whilst gas bubbles may and do emerge long after true vinous fermentation is complete The avoidance of an over prolonged fermentation is a most important matter The alcohol in a wash goes on collecting until a point is reached at which it is present in sufficient amount to check any further action of the yeast From this point onwards, fermentation dies away and the active bubbling of the liquid ceases Entangled gas bubbles, however, may escape for days afterwards so that an instrument which shows when alcohol is no longer being formed has to be employed A daily examination of the fermenting wash by testing the gravity with the saccharometer is thus of the highest importance to decide when alcoholic fermentation is really complete (as is further explained in the succeeding section) The proper way of determining whether fermentation is complete is by (1) observing the temperature by means of a thermometer, and (2) seeing whether the specific gravity of the wash is stationary or not by means of a saccharometer At the commencement of fermentation, the temperature begins to rise on account of the heat produced by the chemical changes occurring, it attains a maximum, or highest point, and then falls to a stationary point The specific gravity steadily falls as fermentation proceeds, as the heavier sugar is turned into the lighter alcohol and gas When the specific gravity is at a stationary point, fermentation is complete

Example.—

Stage of fermentation	Specific gravity	Alcohol volume percentage	Acidity percentage	Temperature, Fahr
On setting up fermentation	1100 6	0 4	0 36	70°
1 day later	1056 7	6 4	0 51	80°
2 days later	1028 9	9 4	0 81	75°
3 " "	1024 8	9 7	1 0	70°
4 " "	1024 8	9 6	1·0	70

The above records show that (1) the specific gravity fell steadily (attenuation) and was stationary three days after fermentation began, (2) the proportion of alcohol formed in the wash steadily rose to a maximum on the third day and on the fourth day fell very slightly, in this case probably because of loss from evaporation, since no increase of acidity occurred at the expense of the alcohol, (3) the acidity rose steadily to a maximum on the third day after fermentation, (4) the temperature rose to a highest point and then fell, remaining stationary on the third and fourth days It will also be observed that it is a record of continuous observations that is needed, and that unsystematic or occasional testing is useless

As soon as the fixed attenuation point has been reached there should be no delay in running the wash into the still and starting distillation If there is a delay, a second fermentation begins, and this is really of the nature of decomposition or putrefaction In such a case, harmful volatile substances are apt to be formed in the wash, and the change most readily noticed is its increasing sourness and disagreeable odour

In the indigenous method of working *mahua* it is impossible to obtain the original gravity by the saccharometer, but by using the diffusion process this difficulty is overcome It is claimed that, if the *mahua* flowers are placed in the still, a fuller flavour is obtained, but the diffusion process gives a like result if the spirit is distilled to a fairly low strength

54 *Necessity of cleanliness*—An essential to a properly controlled fermentation which cannot be too frequently insisted upon is absolute cleanliness at all stages of the process This should commence with the water supply, which should be ample and of good quality, and with the stores for the bases, which should be well floored, pukka buildings, and kept as free from flies as possible The fermenting sheds should have pukka brick roofs or other cool roofing material, and pukka floors, which latter should be regularly washed down The spilling of wash on the floor should be avoided Fermentation should be carried on in vats, which should periodically be thoroughly cleaned, and not in earthen *ghurrahs*, which lend themselves to the accumulation of dirt Neglect of these precautions leads to the contamination of the fermenting wash by microscopic germs which produce acids, thus helping to sour the liquor, or by wild yeasts which produce defective fermentation and tend to prevent the action of the more suitable varieties of yeast when present Even greater precautions are necessary when special yeasts are prepared for addition to the wash

55 *Method of cleaning fermentation vats*—In distilleries where steam is available it should of course be used for cleaning out the vessels and this

should be followed by scrubbing When steam is not available, the following process may be adopted —

> As soon as the wash is run out of the vats they should be well cleaned with hot water and a thin paste of lime (quicklime if procurable) should then be thoroughly brushed over the interior Before refilling the vats with wash the solution of lime should be carefully washed off with water up to the probable surface level of the wash to be placed in the vat Above the level of the wash the lime coating should be allowed to remain undisturbed as it will be found greatly to assist the cleaning of the vat afterwards all scum thrown up and adhering to the sides being easily removed along with the lime Sulphuric acid is used in some Indian distilleries for cleansing the fermenting vats after use This is unobjectionable The strength in which it may be used is 1 part of strong commercial sulphuric acid to 40 parts of water This is roughly about half a pint of the acid to an ordinary sized bucket (of 2½ to 3 gallons capacity) filled with water Such buckets should be wooden and not metal as the acid will act on the latter and corrode it

56 *Description of the thermometer and mode of use*—Thermometers are instruments for measuring temperature by means of the expansion by heat or contraction by cold of a column of mercury in a capillary or hair like tube Every thermometer has a round or cylindrical bulb at one end of this capillary tube and the opposite end is closed Between the top of the capillary tube and the top of the mercury column is a vacuum or space empty of air The expansion of the mercury column is measured by a scale which is graduated either on the stem itself (the preferable form) or on an ivory or wooden frame to which the bulb and stem are attached Mercury is chosen as the liquid best suited for use in a thermometer as its expansion is regular and it only freezes or boils at temperatures never encountered in Excise work The thermometer is divided into a number of divisions (degrees) according either to Fahrenheit s or the Centigrade (Celsius's) scale In Fahrenheit s which is that ordinarily employed in India for Excise work, the higher point corresponds to the temperature of boiling water but the zero or 0 point represents the temperature obtained by mixing equal weights of snow and ammonium chloride The scale between these two points is equally divided into 212 degrees Fahrenheit s thermometer if placed in melting ice reads 32 degrees—the freezing point if placed in boiling water, 212 degrees The Centigrade thermometer is divided into 100 degrees between the freezing and boiling points of water,—the freezing point is 0 or zero, and the boiling point of water is 100°, hence the name Centigrade, or 100 steps scale Temperatures below zero are denoted by the *minus* sign

To convert a temperature expressed in degrees Fahrenheit to degrees Centigrade subtract 32 multiply the result by 5 and then divide by 9 To

The above records show that (1) the specific gravity fell steadily (attenuation) and was stationary three days after fermentation began, (2) the proportion of alcohol formed in the wash steadily rose to a maximum on the third day and on the fourth day fell very slightly, in this case probably because of loss from evaporation, since no increase of acidity occurred at the expense of the alcohol, (3) the acidity rose steadily to a maximum on the third day after fermentation, (4) the temperature rose to a highest point and then fell, remaining stationary on the third and fourth days It will also be observed that it is a record of continuous observations that is needed, and that unsystematic or occasional testing is useless

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58 *Bates' saccharometer* —Bates' saccharometer* consists of a rectangular stem attached to a pear shaped bulb or "float". A ring or "stirrup" is attached to the lower end of the "float," and, by means of a conical hole made in the underside of the stirrup, a number of poises of different weights and bulks can be attached In this way an instrument reading from 1000° to 1150° or 970° to 1150° is obtained

The scale has thirty divisions, zero being at the top of the stem, and the poises usually provided are numbered 970, 1000, 1030, 1060, 1090 and 1120 the first of which is used only in distilleries and the rest in breweries also In making tests with the saccharometer a suitable vessel is filled with a sample of the wash to be tested By a process of trial, or previous knowledge, that poise is attached which will cause the instrument to give a reading on the scale, then the number which is read off the scale is added to the number on the poise and the result is noted The temperature of the liquid is then noted and the true specific gravity (*i e*, at 60°F) is read from the tables for correction of temperature supplied with the instrument

Example —Suppose the saccharometer indicates 13 on the scale with the 1030 weight attached and the thermometer at 74°F

Apparent specific gravity is	1030 + 13 = 1043
As corrected by tables	1044 7°
	= 1045° for practical purposes

In all cases the corrected specific gravity must be recorded Fermenting and frothy samples must be allowed to stand a few minutes previous to being tested and a little more of the sample added to the vessel to displace the froth If, after displacement of the froth, the disengagement of gas is still violent, some small allowance should be deducted from the scale reading

A poise whenever it is attached to the instrument, should be given a slight twist to the right to fix it lightly but securely in the stirrup hole and, after use, should be released by a slight twist to the left to avoid damage to the peg and hole joint

As a brass gilt saccharometer rapidly corrodes, if carelessly treated when used for acid washes, and as such corrosion affects its accuracy, great care must be taken to rinse the instrument in clean water immediately after use It should then be carefully dried with a soft cloth before replacing it in its case

Directions for packing saccharometers when despatched for standardisation or other purposes and for preserving wash samples during transit are given in Appendix II

* For an account of the theory of Bates s saccharometer, *see* Appendix I

CHAPTER IV.

Types of Stills and the Process of Distillation.

59 *Description of the process of distillation*—The object of distillation is to separate (*a*) the volatile alcoholic constituents of the wash from the non volatile constituents, which are left behind in the still and are either allowed to run to waste or used as cattle food or fuel, and (*b*) the more volatile constituents from the less volatile Stills may be considered here in two great classes, pot stills and patent-stills The pot still is the simpler form of still Its main features are —a "retort" "pot" or "kettle" into which the fermented wash is run This is heated by a furnace underneath or by steam coils which are immersed in the contents, or in some rare cases by a "steam jacket' From the kettle the alcoholic vapours pass on into a head piece and thence escape through a tube or lying pipe to a worm which is surrounded by cold water Here the vapours are condensed again into the liquid condition They are then collected in a receiver

60 *Types of stills in use in India*—While by far the larger number of stills used in India are pot stills, these vary in their details and degree of elaboration in different Provinces It will be sufficient to mention a few examples here

61 *United Provinces' type*—A good example of the more primitive is that used in the United Provinces This is a still of a capacity of from 20 to 50 gallons The head of the still is earthenware, being merely an inverted bowl which is connected with the receiver by a bamboo pipe fitted into a hole in the side of the still head The joint between the head and still body is closed with clay The still is charged with wash and the spent wash after distillation is completed is emptied out, after removing the head and its attachments As a general rule, no condensing worm is fitted between still and receiver Hollow bamboos wrapped round with string (which may occasionally have water thrown ontocool the contents) are used as condensers The receiver is usually immersed in water with the object of condensing the vapours passing into it during distillation The still is heated by an open furnace No attempt is made, as a rule, to regulate the heat One of the chief defects in working such stills is this unregulated still furnace which leads to too quick distillation and even to boiling or frothing over ("priming') of undistilled wash and also to the production of certain impurities, *e g*, furfural, by overheating the solid matter of the wash in the still

The chief structural defects of the above pattern of still are —

(1) the absence of any device for purifying the vapours such as a "rectifier" or a "doubler," terms which will presently be explained,

(2) the quite inadequate condensation of the vapours passing from the still to the receiver There is practically no condensation till the spirit vapour enters the receiver. Not only does this defect lead to the production of an impure liquor, but there is considerable loss of alcohol from the end of the pipe opening into the receiver The alcohol can frequently be seen to issue uncondensed in the form of vapour and to escape into the air,

(3) the troublesome arrangement for emptying the still of the spent wash,

(4) the want of security for revenue and distiller in working an unlocked still, which leaves the way open to abstraction of spirit by theft and to loss of spirit from the open receiver by evaporation

A further defect which has been detected in the very similar stills used n the Bombay toddy distilleries is copper contamination of the liquor by neans of the wooden pipe connecting the copper still with the receiver

Here the acid wash corrodes the copper kettle, producing copper salts he wash froths or spirts up into the wooden pipe, which thus becomes aturated with coppery liquor *This coppery liquor spreads along the fibrous* nner surface of the wood and thus reaches the copper receiver The liquor ollecting in the receiver, which is often periodically tinned inside, is thus ound to contain poisonous amounts of copper salts

62 *Bombay or Persian still* —Another form of crude still is the "Bombay" r "Persian" still These stills are of copper and are often of 100 to 300 allons capacity The still head is of wood and is removable in order to fill r empty the still From the top of this rises a column of copper or other netal which is connected by a pipe with the worm This column acts slightly s a rectifying agent and in some stills contrivances exist for increasing this ction by cooling it with water The still is, in many cases, heated by a coil f steam pipes fitted inside it and placed close to the bottom The spent wash is in some cases discharged from the still by a special valve or cock Worms in tubs are used for condensation, but are usually of an extremely faulty nature The structural defects noted in stills of the above pattern re—

(1) The wooden still head becomes permeated by impurities which to some extent are steamed out of the wood in the course of subsequent distillations and are carried over to add to the impurities of the liquor. The cumbersome mode employed in many of these stills of filling and emptying the still is also to be noted.

(2) The steam heating apparatus, when used, though perhaps more economical than open firing and certainly more controllable, is somewhat difficult to remove The coil of piping is hence seldom, if ever, removed, so that cleansing of the inside of the still is neglected, with the result that very filthy collections of putrefying wash come to lie under the coil and the floor of the still is corroded by the stale acid wash This leads to defects in taste and wholesomeness of the liquor

(3) The worms are usually too short and often too wide and are not proportioned to the capacity of the still The principle that the worm should taper throughout is generally neglected

Important defects in working are that a proper flow of cold water in the worm tub is not kept up during distillation and that the receivers and the "spirit safes,' where used, are often open or unlocked, with consequent risks of waste and abstraction

63 —*Russa still* —A pattern of still which has found favour especially in Bengal is that known as the Russa still (from Russa distillery near Calcutta) See Plate I This consists of a cylindrical copper kettle with a dome shaped breast, F, from the centre of which a short wide pipe C the head leads to the worm, K Water is led into a perforated collar D placed round the bottom of the head and trickles thence through small holes over the surface of the breast itself, where uniform distribution is secured by means of a jacket of gunny cloth applied to the breast The water is collected by an upstanding rim B, at the circumference of the breast and is led off by an outlet pipe of suitable dimensions E The under side of the still breast thus acts as a water cooled rectifying surface for the alcohol vapour as it rises inside the still body, and the rectifying effect is increased by a baffle plate of special construction placed inside the still, *see* Plate II This plate which is of somewhat less diameter than the still body, is shaped to the same curvature as the domed breast itself and upon its upper, convex surface is riveted edge wise a ribbon of metal so as to form an upstanding flange of uniform depth

The course of this flange is that of three or four coils of a loosely wound spiral Thus, when the baffle plate is bolted up against the dome as closely as the flange permits, the space between the plate and the dome is converted into a flattened and spirally wound box or tunnel one end of which opens under the still head and the other into the still body at the edge of the baffle plate When the vapours from the boiling wash rise over the edge of the baffle plate they cannot at once pass up into the head, but are obliged to travel through the spiral box or tunnel where they are in contact with the under surface of the externally cooled dome Only the lower boiling portions

Plate I

RUSSA STILL.

WATER MAIN

C

D

F

B

G

K

K

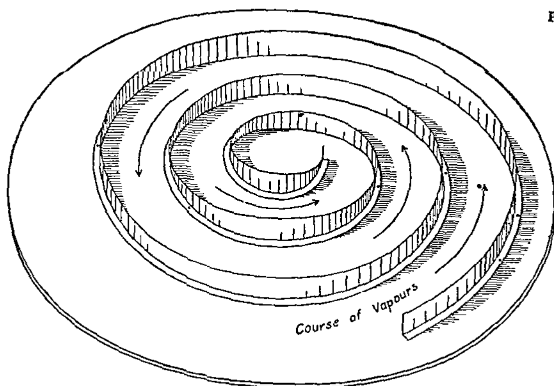
K

Y

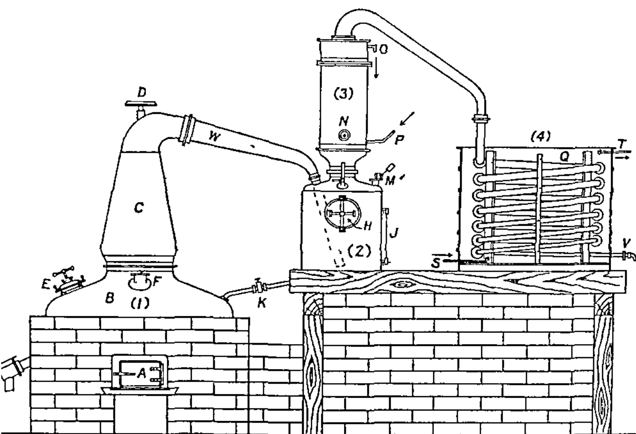
Masonry
n section

To Receiver

Plate II



POT STILL.



1. THE STILL
   - A Furnace Door.
   - B Breast
   - C Head.
   - D Gear wheel for Rouser
   - E Manhole
   - F. Valve.
   - G Discharge Cock.
   - W. Lying pipe.
2. THE DOUBLER
   - H Manhole.
   - J. Gauge
   - K Return pipe.
   - M Safety Valve.
3. THE RECTIFIER.
   - N. Manhole.
   - O. Cooling water Outflow
   - P. Cooling water Inflow.
4. THE CONDENSER.
   - Q. Worm Tube.
   - S. Cooling water Inflow.
   - T. Cooling water Outflow.
   - V. End of worm.

of the vapour, therefore, reach the end of the spiral and escape up the head, whilst higher boiling constituents are condensed and returned to the still body

A tub, G, placed on a level with the breast is employed as a wash charger when sugar washes are used but *mahua* washes containing solid matter are fed through a manhole in the still body Heating is by direct firing but in some cases the still is surrounded to three quarters of its height by a brick wall with a space between which acts in some measure as a flue

64 *Frequent defects in working Russa stills*—This still which is based on a pattern of French brandy still gives good results if the flanged baffle plate is so carefully fitted under the dome that the whole of the vapour is compelled to travel through the spiral chamber and no portion escapes across the top of the flange to the still head In practice the plates in the locally made stills are not bolted sufficiently tightly and the vapour escapes condensation Again though some of the stills have water fed to the dome from the cold water main in others only the overflow of the condenser is used and that sometimes is so inadequate that little condensation in the spiral chamber is possible Many Russa stills also have either no proper flue system or have the chimney set at one side directly opposite the open firing place with the result that a through draught is created and the flues are rendered practically useless As a consequence whilst one portion of the still body is unduly heated in fact burnt out before its time other portions are unheated and the flames waste their heat up the chimney

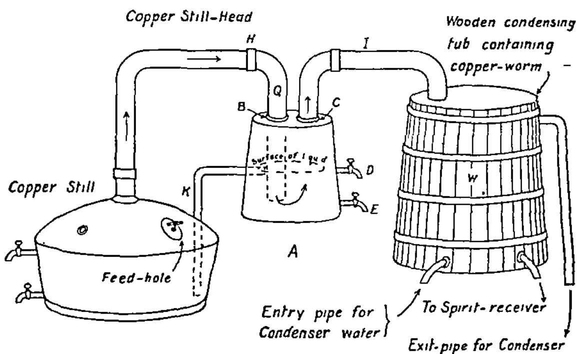
65 *Efficient type of pot still*—The details of an efficient modern type of pot-still may now be considered A diagram of a good example fitted with both doubler and rectifier is here given (Plate III) The principle of the simplest type of pot-still is a pot or kettle in which the fermented wash is heated so that its volatile constituents are driven off to be condensed in a cooling worm and then collected in a receiver The kettle or pot or still proper ought to be built comparatively shallow The bottom should be concave to the fire since this form is structurally stronger and exposes a larger heating surface while the curved surface assists draining through the discharge cock The convex upper surface of the still called the breast should be rather wider than the bottom From the middle of the breast a pipe rises to a varying height and this is occasionally bulbed or commences in an expansion tapering to a narrow end like a pear These contrivances are meant to cause purification and strengthening of the spirit by re condensation of the vapours which is termed rectification This up pipe is termed the head In the simplest form of still the head opens into a pipe (called the ' lying pipe ') leading direct to the condensing worm

66 *Condensing worm*—The worm is one of the most important parts of the still and one which requires more care as regards cleanliness and the

risk of blocking than any other It is formed by a copper pipe, graduated from, say, four inches diameter at the top end to one and a half inches at the end opening into the receiver This is bent into a number of spiral coils The cooling capacity of the coil depends on its area, on the quantity and temperature of the water supply available, and on the rate of distillation Thus *twelve to fifteen coils are usually found to be a satisfactory number for* a moderate sized still For a small, say, 50 gallon still, 6 coils are enough Each coil should be uniform as regards its outside measurement, and should be separated from the other coils by a space of about 3 inches The coils are kept apart by short pieces of solid metal or piping soldered to them outside and placed at intervals of about three feet In addition, about four heavy strap iron braces reaching from the top coil to the foot-coil should be bolted together in pairs one inside and the other outside the coils The lower ends of these braces are bolted securely through the end of the worm tub so as to hold the worm firmly in position The coils must be sloped so that there is a marked "fall" throughout to enable the condensing liquor to run downwards to the receiver This prevents liquor stagnating in the worm and corroding the copper, thus leading to serious copper contamination of the liquor The worm should be so placed in the tub that the lower coil will be about 2 to 6 inches (depending on the length of the worm) above the foot of the tub The end of the worm should project through the tub into the receiver, or, where a 'spirit safe' is used, into it The worm tub is pierced below by a pipe leading cold water into it Another pipe at the top of the tub allows of the outflow of the condensing water These inlet and outlet pipes should ordinarily have a diameter of from two to three inches Thus the condensing water enters at the foot of the worm tub, flows upwards as it becomes hotter and therefore lighter, and passes out at the top of the tub, whilst the spirit vapour is passing downwards inside the worm This counterflow is of importance as being the most effective mode of producing condensation

67 *The safe*—In order to see how the still is running a locked "safe" or box with glass sides is usually fixed between the worm end and the receiver The liquor from the worm end flows into a cup in which floats a small hydrometer (or specific gravity beads) the readings of which show the strength of the spirit at any stage of the distillation An arrangement should also be made by which the stream of liquor from the worm end can be turned into either of two cups so that the stronger "foreshots" may be dealt with apart from the later runnings Or, stop-cocks may be fitted so as to turn the foreshots or first runnings into one receiver, the clean spirit or middle runnings into another receiver, and the tailings or last runnings into that containing the foreshots, or, if required, into yet another receptacle It *is most important that these separate portions (fractions) should be kept* apart in order that the first and third runnings may be redistilled in order further to purify them

DOUBLER.


Copper Still-Head
H
I
Wooden condensing
tub containing
copper-worm
Q
B
C
Surface of liquid
D
E
W
Copper Still
K
A
Feed-hole
Entry pipe for
Condenser water
To Spirit-receiver
Exit-pipe for Condenser

68 *The receiver* —The receiver should be a wooden, cemented or metallic receptacle which should be kept securely locked under Excise and distiller's locks, and should be made sufficiently secure in other respects from risk of theft Separate receivers should be provided for clean spirit and for foreshots and tailings

69 *The doubler* —The above describes the ordinary simple pot-still, but in order to prepare stronger and purer liquor it is often advisable to fit between the still and the condensing worm —(1) a doubler, and (2) a rectifier

A rough sketch (not to scale) is here given of a doubler (Plate IV) and a description of the necessary apparatus follows —The dimensions given are applicable to a still capable of holding a charge of from 600 to 700 gallons

Obtain a stout two headed tub, of one and half inch staves and two inch top and bottom (*see* A, diagram) Length of staves four feet Breadth of tub, forty two inches at the top by forty six at the bottom Cut two four inch holes B, C, in the upper surface and fit a four inch collar flange to each Insert a one inch brass cock E in the side of the tub on a level with the bottom, and another D eight inches above it Fit a two inch pipe K, called the return pipe, into the doubler so that its upper orifice opens eight inches above the floor of the doubler as shown in the diagram and on a level with the upper side cock, D The lower end of this pipe is brazed to a collar flange, by means of which it may be connected with the still Run a four inch copper pipe Q through one of the collar flanges B let the lower end descend to within three inches of the bottom of the tub and the upper end project twelve inches outward, and be brazed to a collar flange H so that it may be connected with the breast of the still The other four inch opening C connects by a four inch pipe I with the worm contained in the worm tub W The doubler is placed midway between the still and the worm its bottom being somewhat higher than the upper surface of the still, and the four inch inlet is turned towards it In this position the inlet Q is connected with the centre of the breast of the still and the outlet I, which is the open four inch flange, is joined to the worm The two inch return pipe K passes through the breast of the still near the edge and is carried downwards inside the still to within two inches of the bottom The apparatus is now ready for use

When about to distil, fill the doubler up to the side cock D with water.* When heat is applied to the still the liquor which it contains vaporizes and passes through the connecting pipe Q from the still into the doubler. Here it meets a resisting force, in the shape of several inches of water through which it must pass or condense

The first portion condenses and returns to the still through the two inch return pipe K As the water in the doubler becomes heated to the degree at which alcohol boils, the alcoholic vapours pass through it, and are, as it were, filtered leaving the heavier bodies behind to be returned into the still

* Before each distillation the doubler must be emptied by the side-cock E and re filled as described with fresh water

in a liquid form It will thus be seen that, although it may take a little longer to run a charge, the product must be purer and of a greater alcoholic strength

70 *Advantages of the doubler*—The doubler has also the following advantages —

(1) it prevents the disadvantages following any priming of the still, the chief cause of which is over firing, as the primings remain in the doubler and do not reach the receiver,

(2) it lessens very markedly the proportions of acids and of furfura —the chief defects in Indian spirits are due to too high proportions of these by products—as these tend to be arrested in the doubler

(3) it affords an additional safeguard against the effects of defective condensation

It can be fitted readily and cheaply to existing patterns of pot stills

The necessity of obtaining a constant circulation of cool water round the worm has already been mentioned In the diagram of the doubler the exit pipe and entry pipe should be at opposite sides of the condensing tub The worm end leading to the receiver pipe should issue from the side of the condensing tub (not through its foot) and should be on the side of the tub furthest from the still

71 *Rectifier*—Between the doubler and the condensing worm it is well to have a "rectifier This, in one of its simplest and perhaps most satisfactory forms consists of a series of narrow vertical pipes placed parallel to one another and cooled on the outside by water passing into the containing cylinder at its foot and out again at its top In these pipes the alcoholic vapours escaping from the doubler, or directly from the kettle where no doubler is in use, are purified by partial condensation or rectification

A description of the process of manufacture of Scotch whiskey in an efficient pot still will be found in Appendix III

72 *Setting up the still*—The still proper should be lower than any of its connections The still foundation is first built to a sufficient height and fitted with fire box and ash pit Then the still is placed in position Next the brick work should be built in, leaving a circular flue round the sides This is almost invariably neglected in native distilleries in India The worm-tub is then set up so that the worm end is a sufficient height from the floor to leave room for the receiver Then the head of the still is connected with the doubler and rectifier, where used or direct with the worm by a copper lying pipe tapering ordinarily from 6 to 4 inches in diameter in a moderate sized still The water reservoir for supplying the worm tub should be on the roof or at a sufficient height to feed readily into the worm tub A two inch pipe should run from it to the tub The outflow

from the worm tub should be placed so that the water can be re pumped after cooling into the reservoir if necessary

73 *Running a charge*—Stills are charged in well arranged distilleries by gravitation otherwise by pumping The amount of the charge should be accurately known and the wash backs may be provided with gauges or other means of telling when the limit is reached Roughly speaking it will be about three quarters of the capacity of the still As a check on over charging a try cock is sometimes put in the still at the level of the top of a safe charge and left open while charging is proceeding so that filling may be stopped as soon as any wash begins to trickle from the try cock

74 *Running foul*—The still must be watched to prevent it running foul When the liquor in the still is heated to the boiling point of alcohol care must be taken that the heat is regulated by drawing the fire or checking by stop cock the supply of steam Otherwise the contents of the still may be carried up to the still head and block the worm or pipes leading to it If this happens the still will be liable to blow up To prevent this—when the still surface becomes heated strike with a hard solid wooden ball or mallet on the still head If a hollow sound results all is well but if a dull sound follows the still is in danger of running foul In this latter case, draw the fire at once Any block of the pipes leading from the still may cause the foot of the still or its head to be blown off

In this connection it should be remembered that cold water run into the still while in full working or thrown on its surface in sufficient amount to cause the vapours inside to be suddenly condensed leads to the space above the wash becoming (relatively) empty of air This if there is a partial block in the pipes leading from the still may enable the weight of the atmosphere (15 lbs to the square inch) to crush or cave in the still Safety valves should be fitted to lessen these dangers

75 *Separation of fore shots and tailings from the middle runnings*—As already stated the first runnings or fore shots are the strongest and usually most impure portion of the distillate This portion or fraction should be run off separately and added to a subsequent charge and further purified by distillation The middle runnings or clean spirit is the potable spirit The tailings or last runnings, which are very weak and impure, should be treated exactly as the fore shots They should not be used for reduction of the clean spirit

76 *Cleaning the worm*—A clean copper worm is practically unaffected by temporary contact with even the very acid liquors common in Indian distilleries Acid spirit and sour vegetable matter of all kinds, however, rapidly corrode a copper worm if left in contact with it for a time and the presence of moisture and atmospheric air greatly helps this process It is most important that no liquid or solid deposit should remain in the worm when it is out of use and that the inside of the worm should dry as completely as possible Serious corrosion is known to take place if the worm

does not slope properly from end to end In this case, acid last runnings collect inside instead of draining away, and the first portion of the next distillate is found to contain a high proportion of copper salts Some distillers now arrange to collect the first few gallons separately merely to avoid copper contamination from such a cause Again objectionable deposits in the worm such as sugar, acids and sour vegetable fibre, occur as the result of priming, *i e*, boiling over of the wash, and, in some distilleries, it is the custom to remove the worm bodily from the tub at stated periods and to treat the whole coil by direct firing in order to burn up such deposits Owing to the coiled and tapering form of the worm, only a few inches can be inspected for dirt and moisture and for the same reason it is impossible to wipe it dry and clean or polish the interior surface with a brush Consequently corrosion is very liable to occur and to escape detection The worms of *mahua* stills require very special attention Such worms have been found constantly to contain a greasy deposit, which may be yellowish white, green or black according to its age and the amount of corroded copper present This deposit is soluble in strong spirit, *e g*, first runnings, and also in acid runnings, and at either the early or late stages of distillation may cause a serious copper contamination of the spirit in the receiver

77 *Methods of cleaning the worm* —Various methods in the past have been adopted of cleaning worms of copper salts produced as above, but none with complete success For instance, filling the worm with water between distillations, thus cutting off the air which is necessary to help corrosion to occur is not sufficient to prevent corrosion Nor will pouring acids or alkalis or water, unless it is boiling, down the worm clean it sufficiently The practice of periodically removing the worm and heating it red hot cleans the worm temporarily but, of course, does not prevent later corrosion Re-distillation of a copper contaminated liquor does not by any means necessarily purify it unless the worm has been sufficiently cleaned before the re distillation Frequently, such re distilled samples of liquor have been found to contain several grains of copper per gallon Excessive amounts of copper have been found in *mahua* spirit made in a still with a doubler or even in a patent still In the former case the water in the doubler had not been changed regularly as it should have been, and in the latter the condensing tubes had been allowed to collect copper grease through ignorance of the facts stated above It may be added that even filling up the worm with solutions of strong acids or alkalis has little or no effect in the case of *mahua* stills owing to the peculiar nature of the deposit This is moreover a costly and cumbersome process

78 *Method recommended for cleaning the worm* —A special investigation of the subject was made at the Central Excise Laboratory as a consequence of which a special method has been designed for removing this deposit as follows —

(1) At the end of each distillation disconnect the spirit receiver from the safe or worm end

(2) Run off the water from the worm tub

(3) Pass steam into the upper end of the worm from a separate boiler where possible, or continue distillation from the residual wash until steam issues freely from the worm end The object of this is to heat the worm by steam throughout its length to, practically, the temperature of the steam so as to melt the *mahua* fat deposited inside the worm The steaming should be continued till no fat comes away from the worm end A period of 15 minutes from the time steam first issues from the worm end may be taken as a guide If the worm is very foul, the steaming will require to be repeated more than once before a marked improvement is effected The test of cleanliness will be the absence of copper from the liquor as shown by the test to be described later as the C E L test

This steam cleaning should be systematically employed after each distillation in pot-stills using *mahua* By continuing the distillation from the residual wash the worm cannot be again fouled to any appreciable extent by the fat from the *mahua* as the uncondensed steam will prevent further deposit of fat There can be no risk of bursting any part of the apparatus as steam must be able to pass where spirit has passed In steam heated stills, steam direct from the boiler should be passed into the worm by means of a side piece It has been ascertained that the worms of most old stills in India are apt to be very foul It would be advisable to submit the worms (when copper is detected in the liquor) to the foregoing treatment in the case of *mahua* stills regularly, as the mischief occurs in them continuously, and in the case of non *mahua* stills to remove existing accumulations, when the test shows that the liquor is becoming at all contaminated

Copper contamination may be considerably reduced by the use of a special form of condenser One such is multi cylindrical and the spirit passes between two water cooled surfaces, whilst in another, it passes down a series of vertical tubes contained in a cylindrical water jacket It is claimed for these condensers that they are economical of space, and efficient in action if the water supply is ample

79 *Boiling points of alcohol and its by products*—Before considering the purification of spirits as a practical operation, certain facts regarding the boiling points of mixed liquids must be referred to Water, alcohol and the various spirit by products, when in a pure state, have each a boiling point which is constant under standard conditions If two or more, however, are mixed and distilled, these boiling points are changed Thus, pure alcohol boils at 172° F, and pure water at 212° F, but mixtures of the two boil at intermediate temperatures In the accompanying table, which shows the effect of distilling mixtures of water and alcohol in a pot-still, the different boiling points of mixtures containing 1 per cent, 10 per cent, 50 per cent, and 92 per cent, of alcohol should be noted in proof of this

point, also of the fact that the more alcohol there is present, the lower the boiling point.

Proportion of alcohol in the boiling liquid in 100 vols	Temperature of the boiling liquid	Proportion of alcohol in the condensed vapour in 100 vols	Proportion of alcohol in the boiling liquid in 100 vols	Temperature of the boiling liquid	Proportion of alcohol in the condensed vapour in 100 vols
92	171.0 F	93.0	20	189.5 F	71
90	171.5 F	92.0	18	191.6 F	68
85	172.0 F	91.5	15	194.0 F	66
75	173.6 F	90.0	10	198.5 F	55
70	175.0 F	89.0	7	200.6 F	50
65	176.0 F	87.0	5	203.0 F	42
50	178.1 F	85.0	3	205.1 F	36
40	180.5 F	82.0	2	207.5 F	28
35	182.6 F	80.0	1	209.9 F	13
30	185.0 F	78.0	0	212.0 F	
25	187.1 F	76.0			

It will further be seen from the table that the 92 per cent. mixture boils at 171° F., that is 1° F. lower than alcohol itself, and yet the condensed vapour contains 7 per cent. of water which has thus distilled over at a temperature 41° F. below its proper boiling temperature. The 10 per cent. mixture boils at 198.5° F. That is to say an ordinary wash must be heated 26½° F. above the natural boiling point of alcohol before the mixture boils. Thus the mixing of water and alcohol affects the boiling points of both liquids. Again, from the table, it will be seen that, when the amount of water in the mixture is large, a large percentage of it is removed by distillation, and when the amount is small the percentage removed by one distillation is disproportionately smaller. [Example: from a wash containing 90 per cent. water, 50 per cent. of the water is removed, whilst from a strong spirit (92 per cent. alcohol) only 13 per cent. of the water present is removed by one distillation.] Thus the removal of water becomes more and more difficult the less there is of it. Exactly the same laws govern the removal of by-products from mixtures with alcohol and water. Their natural boiling points are changed so that, instead of boiling steadily at one temperature, they distil over at a variety of temperatures and the difficulty of removal increases as the amount present becomes less. The following is a list of the more important by-products and their natural boiling points when in a pure state:—

Boiling points of various Alcohols (omitting decimals).

	°Cent.	°Fahr.
Ethyl Alcohol	78	172
Normal Propyl Alcohol	97	206
Iso Propyl	83	181
Normal Butyl	117	242
Iso Butyl	108	226
Iso Amyl	129	263

For convenience of reference there may be contrasted with these the approximate boiling points of the other chief by products of alcohol (to be described more fully in Chapter V) —

	°Cent	°Fahr
Acetic aldehyde (acetaldehyde)	21	70
Acetic ether	77	171
Butyric ether (Ethyl butyrate)	120	248
Furfural	162	324
Acetic Acid	118	244

Two of these boil at temperatures lower than alcohol For the most part, they collect in the first runnings or "foreshots," and hence the necessity of separating "foreshots," but small quantities remain until the middle fraction, despite the rise in temperature Others in the list boil at temperatures exceeding that of water In the main, they distil over after most of the alcohol has been collected, that is in the last runnings or tailings, and hence the advantage of collecting tailings in a separate receiver Portions of, for example, acetic acid and furfural are found in the middle runnings of a pot still, which means that they have distilled over at temperatures considerably lower than their natural boiling points Removal of water and by products from mixtures with alcohol is an easy matter up to a certain stage, though always a slow operation It requires the complicated modern patent-still, in which every particle of vapour is redistilled many times, to separate by products with anything like completeness, and even, this at its best leaves at least 3 or 4 per cent of water mixed with the alcohol

The following table will perhaps give all the necessary information required in practice for the Excise officer's purposes —

	Produced chiefly during	Chiefly distilling over
1 Acids—		
(a) Volatile	Fermentation	Late
(b) Fixed	Casking	Not at all
2 Ethers (compound ethers or esters)	Fermentation and distillation	Early
3 Furfural	Distillation	Late
4 Aldehydes	Fermentation and distillation	Early
5 'Fusel oil (a mixture of higher alcohols and higher boiling point Ethers' etc)	Fermentation	Late
6 Volatile alkaloidal bases	Uncertain	Late

80 *Rectification* —Rectification is the process of further strengthening and purifying weak alcoholic liquors or washes by re distillation It is essentially, repeated distillation of the liquor in portions called fractions, so as to separate the impurities at the most favourable stages An efficient patent still produces highly rectified alcohol at one operation The product

when highly rectified does not betray its origin by any characteristic flavour or odour and is hence termed silent spirit A dephlegmator is a still head or rectifying apparatus used in strengthening and purifying spirits by rectification The broad principle underlying the use of such rectifying apparatus is the fact that it is impossible by a single distillation in a simple pot still to separate two substances even if they have different boiling points because the substances boiling at lower temperatures will always mix with those boiling at higher temperatures and *vice versâ* Therefore, repeated distillation is needed and this is carried out by condensing the vapours in columns and concentrators provided in the rectifying apparatus Plates of metal or other obstacles placed in a rectifying column partly condense, by cooling, the alcoholic vapours coming in contact with them The condensed liquor falls back and meets the rising alcoholic vapour which again turns it into vapour which goes forward to the condensing worm and receiver so that the process is one of strengthening and purification by means of a process of repeated cooling and revaporising The first portion of the distillate contains a mixture of aldehydes and ethyl alcohol, and this mixture boils at a lower temperature than ethyl alcohol alone. This mixture is sometimes loosely called ether The next fraction consists of clean or rectified spirit, which is the purest spirit obtained during the distillation The early portions of this fraction contain a higher amount of aldehydes than the later, and the later portions in turn tend to contain relatively more higher alcohols or, as the mixture of these is termed, fusel oil The third fraction, then consists of a small amount of ethyl alcohol and a relatively large amount of fusel oil or higher alcohols which have the highest average boiling point of all The simplest form of rectifier for a pot still is that described at paragraph 71 More complex apparatus is usually constructed after the type of Savalle's rectifier or of that of Pumpe or Heckmann These, however, are scarcely ever met with in India and hence hardly merit further notice here

81 *Patent stills*—By the use of a patent still, strong spirit is obtained in one operation, *i e*, redistillation is unnecessary, and the process can be, and usually is, conducted without interruption hence the term "continuous distillation" By the use of such stills the wash is thoroughly exhausted of all alochol and the strength of the resulting spirit is also much greater than can be got by the pot still There is a large variety of patent still plants on the market some of which work interruptedly while others are meant only for continuous working For large operations the patent still is ordinarily the cheapest but in India, as the plant requires skilled supervision, the cost of working becomes correspondingly greater

The use of pot or patent still is largely a question of the scale of the distilling operations For small amounts of wash a pot still is naturally much more economical For large quantities of thin washes the patent still is more economical, and further it turns out a much higher strength spirit

than does the average pot still But a patent still is often not suitable for ordinarily prepared *mahua* or other thick washes as the pipes used are generally too narrow for thick washes

82 *Principle of continuous distillation*—The principle of continuous distillation is as follows —

A continuous stream of fermented wash advances against a current of steam The difference in temperature of these two currents is enough to deprive the wash of all its alcohol, the spirit passing over to the steam The steam thus mixed with alcohol passes into two columns named the "rectifier" and the "analyser" ('dephlegmator') and is there further purified and strengthened, and the wash, as spent wash, passes out of the apparatus

83 *Coffey's Still*—The original type of patent-still is Coffey's which was invented by an Englishman of that name and was patented in 1831 The still (Plate V) is arranged in two columns, one of which is called the rectifier, the other the analyser Each column is sub divided horizontally into a number of chambers of wood braced together in an iron frame The chambers are separated from one another by means of copper plates which are provided with a large number of small perforations Each plate is also provided with a safety valve and a drop pipe The latter stands up about an inch above the plate, and passes through the same into a cup on the plate below These drop pipes and cups are arranged at alternate ends of the succeeding chambers

The still is operated as follows —

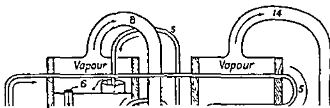
Steam is passed in at the base of the analyser and when both columns are filled with steam (the communication between the two being by the pipe marked 8 in the diagram), the wash is pumped from the still charger to near the top of the rectifier by way of the pipe marked 5 whence it pursues its course to the bottom of the rectifier in the continuation of pipe 5, which traverses each chamber twice by means of a double bend, as shown in the diagram A double object is achieved by this arrangement In the first place the wash is heated by the ascending steam and vapours, and, secondly, the latter are cooled by the descending wash There is thus a saving of fuel and of condensing water By the time the wash reaches the base of the rectifier it is almost at boiling point, it passes on in a continuation of the same pipe to the top of the analyser and there it is discharged upon the perforated plate forming the base of the top chamber of the latter The ascending steam being under pressure bubbles through the wash, but prevents it from passing through the small perforations, and the wash cannot pass to the next chamber until it has

filled the first chamber to the level of the top of the drop pipe It then overflows and passes to the plate below The cups into which the drop pipes dip act as a seal and prevent the steam passing upward through them Thus the wash gradually finds its way from the top to the bottom of the analyser and passes out of the latter by the spent wash tube The steam meanwhile has been passing continually upwards through the wash by means of the perforations in the plates The wash is gradually deprived of its alcohol and other volatile constituents and by the time it reaches the base of the analyser should be practically free from alcohol The alcoholic vapours mixed with steam, pass over from the top of the analyser to the base of the rectifier by the impure vapour tube 8 Thence the vapours pass up the rectifier from chamber to chamber, and in so doing are gradually cooled by the cold wash descending by the pipe 5 already referred to The less volatile constituents of the mixed vapours gradually condense and fall to the base of the rectifier and thence pass to the "hot faints receiver marked 15 A in the diagram

Plate V

COLUMN No 1 (Analyser)

COLUMN NO 2 (Rectifier)



COFFEY'S DISTILLING APPARATUS.

Order of process

1. Vat for crude liquor.
2. Charger for Still.
3. Additional Charger.
4. Pump.
5. Pipe conveying liquor to be distilled. Col No. 2 containing No. 5 pipe, impure vapour from Col. No. 1 and dumb plate where hot distillate is drawn off, Col. No. 1 containing liquor descending from diaphragm to diaphragm and ascending steam from boiler.
6. Liquor spreading over diaphragm.
7. Spent liquor.
8. Vapour from steam and liquor to bottom of Col. No. 2
9. Vapour ascending to Col. No. 2
10. Plate where hot product condensed is drawn off.
11. Hot product condenser.
12. Finished product.
13. Impure product for re-distillation.

13a. Impure product to Still charger.

14. Uncondensed vapour to be condensed in 14a and conveyed by 13 and 13a to Still charger.
15. Impure Spirit liquid for re-distillation through 15a and 15b to Col. No. 1.
16. Steam boiler.

At a certain point in the rectifier a temperature prevails which roughly corresponds to the condensation temperature of ethylic alcohol In this region the ordinary perforated plate forming the base of the chambers is replaced by a stout copper sheet, pierced by a fairly wide pipe which stands up about two inches above the level of the copper sheet The latter is termed the dumb plate A pipe with two branches is fitted in position as indicated in the diagram to drain all liquid condensing on or falling back on this plate Under normal conditions of working the greatest part of the ethylic alcohol condenses naturally on or above the dumb plate, but in order to make the condensation more complete, some of the chambers above the plate are sometimes fitted with coils through which cold water is passed The spirit from the dumb plate is, according to its quality, run by one or other of the branches from the draining pipe to the "feints,' or "impure distillate" receiver, or to the "spirit" or "finished distillate' receiver In practice, if the still be working properly when the pure spirit commences to be collected, it runs continuously until the close of the distillation

Thus at the beginning of the distillation, when the spirit is impure and at the end, when it is not of sufficient strength, it is allowed to pass into the feints receiver, and is pumped back from there to the still The ' hot feints," which are collected in the receiver marked 15A, consist of a mixture of weak ethylic alcohol with an excess of fusel oil, that is to say, of higher alcohols, fatty esters, etc, these hot feints are pumped continuously throughout the distillation to the analyser, and there re-distilled

From the above description it will be seen that the process of distillation which is carried on by steam in Coffey's patent still is continuous and that the low wines are not collected as in the case of the pot still, but pass on to the rectifying column in the form of vapour, where they are resolved into strong spirits and feints At the end of each distilling period, which occupies two or three days, the fusel oil can be removed from the hot feints receiver, frequently this is done by adding water to the liquid, when fusel oil rises to the surface, and may be skimmed off and sold for use in the arts and manufactures

84 *Ilges' continuous still*—The apparatus shown in Plate VI works in a rapid automatic manner by means of regulating contrivances for the admission of wash steam and cooling water and for the removal of the spent wash The wash regulator consists of a large beam scale which weighs into the apparatus a stream of constant size sufficient completely to fill the wash

column A In place of separate bottoms the wash column is furnished with plates having a downward slope The plates, springing alternately from the axis and the wall of the column are furnished with ribs in such a way as to turn the wash alternately to the right and left as it flows down the column A pressure gauge is shown in the figure at " m " and is connected to the steam regulator By means of this latter either exhaust or live steam may be passed into the wash column according to the distiller s requirements The steam enters the bottom of the wash column, and, rising upwards, passes between the ribs and so penetrates the wash very thoroughly

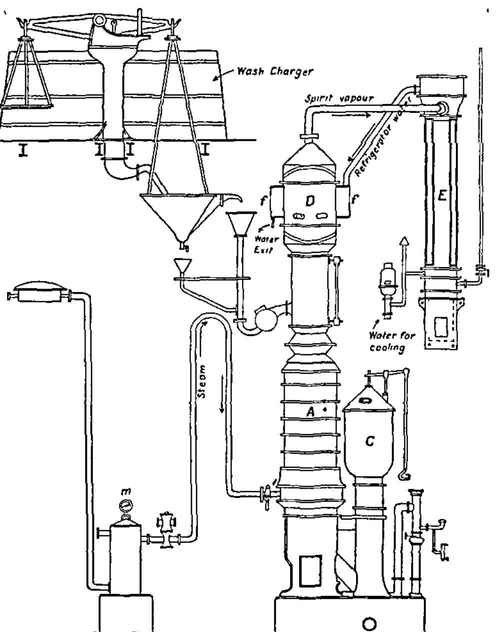
The vapours evolved in the wash column subsequently pass into the dephlegmator D The chambers of the dephlegmator consist of square, cast iron boxes in two walls of which horizontal cooling pipes are embedded in rows The cooling water flows inside the pipes and the inter spaces between the latter are filled with porcelain balls, so that vigorous rectification is effected The rectified vapours leave the top of the dephlegmator and pass into column E, which is an ordinary condenser

The removal of the spent wash is accomplished by the outlet regulator C which is designed so that the introduction of the wash and the removal of the spent wash are exactly balanced The apparatus is provided with a water regulator, shown in the diagram as the condenser water inlet, which ensures uniform and constant pressure The water passes upwards through the condenser E, and then passing from the top of the vessel by the down ward pipe to " f ' passes through the pipes in the dephlegmator D and is discharged at " f " on the other side It is of the utmost importance to ensure definite temperatures in the dephlegmator by automatic control of the quantity of water circulating through the cooling apparatus On the proper regulation of the temperature depends in great measure the success ful separation of the fusel oil, for the higher the temperature inside the dephlegmator the greater the amount of fusel oil which passes over into E

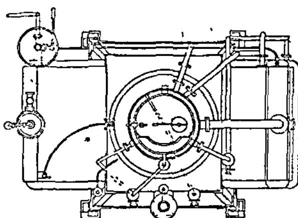
85 *The Guillaume still*—Another useful pattern is the Guillaume still (Plate VII) In this the wash enters K, which is a small cistern containing a floating ball and lever attached to a valve on the wash pipe By means of the latter contrivance the wash in the cistern is always maintained at the same height

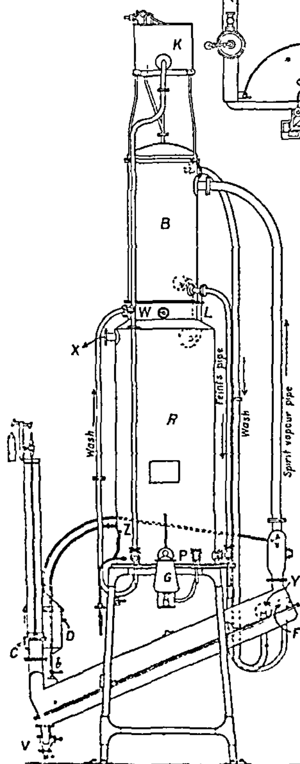
The wash descends through the pipe marked " wash " on the right hand elevation The pipe descends through the bottom of the column so that the control tap may be accessible At this point the wash pipe may enter the lower cylinder, or condenser at P, or it may turn upward and enter the upper condensing cylinder at W (left hand diagram) In the latter case water must be used for condensing in the lower cylinder and will enter at P and

ILGES' STILL.

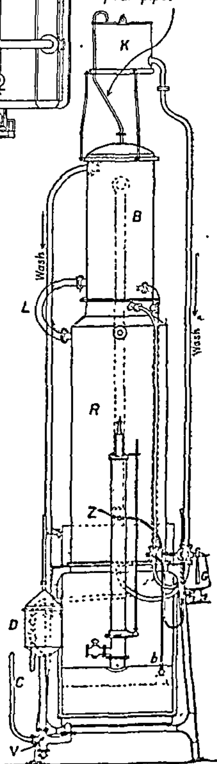

Wash Charger
Spirit vapour
Refrigerator water
D
f
f
E
Water Exit
Water for cooling
Steam
A
C
m

GUILLAUME STILL.





SIDE ELEVATION.



END ELEVATION.

and emerge at X (left hand diagram) In one type of the still the condensation and cooling of the spirit is accomplished entirely by means of the wash, and the wash pipe is diverted and attached to P accordingly The upper and lower cylinders are separated by a diaphragm and, if water is used in the lower one, there is no internal opening between the two, but when wash is used for condensing, a moveable plug fitted into the diaphragm is removed and the two cylinders form one combined condenser and cooler The upper cylinder contains a number of parallel vertical tubes The wash passes through these while the spirit vapour condenses on and around them and collects on the lower plate into which the tubes are fitted The lower cylinder contains a large coil in which some spirit is condensed and the whole cooled by the wash or water which has entered at P The wash having entered the lower cylinder R rises and passes through the opening in the diaphragm into the tubes contained in upper cylinder B, until it overflows into the pipe marked "wash" (left hand diagram) It then descends and enters the inclined distillation column at Y (left hand diagram)

The wash descends the column being diverted from side to side of the column by baffle plates which fit alternately close up to the left and right hand sides of the lower part of the column

The steam, which enters at D, where connection with the steam pipe is made, rises up the column and in order to do so it has to pass alternately over and under the baffle plates, and must also force its way through the wash and in doing so it quickly raises the temperature of the descending wash to boiling point

Consequently the wash is practically exhausted of spirit by the time it reaches the bottom of the column and escapes at V, the spent wash outlet pipe The baffle plates are fastened alternately to the top and bottom of the upper and lower halves of this column respectively The spirit vapour rises through the pipe at the top of the inclined distillation column (*see* left hand diagram) The vapour escapes into B and is condensed by contact with the vertical tubes through which the wash is passing Some of the spirit and most of the impurities collect on the plate into which the tubes are fitted, and when the liquid rises to the level of the opening of the feints pipe (*see* left hand diagram) it overflows and runs down that pipe and back into the inclined distillation column at F (*see* left hand diagram) The purer spirit vapour which has not been condensed in B passes through the external elbow tube at L into the coil in the lower cylinder R where it is condensed and emerges from the pipe terminating at G, the inspection safe, whence it passes to the spirit receiver Any other spirit vapour which is not condensed escapes through the pipe marked "uncondensed spirit vapour pipe" and is conveyed to the bottom of the wash regulating tank, where it becomes absorbed in the wash A pressure of 40 to 60 lbs has to be maintained on the steam inlet valve which is contained in the column C The exact weight to be attached

to the lever has to be determined experimentally The proper balance of pressure between the incoming wash and the steam is automatically regulated by means of the apparatus D which contains a float with a rod attached to it and the spent wash outlet valve V (on right hand diagram) From the top of D a pipe passes to the head of the inclined distillation column so that there shall be no internal resistance to the free action of the floating valve In order to test the vapour of the spent wash the small pipe which emerges from "b" is attached near the bottom of the inclined column Some of the vapour from the lowest point of the column passes up this tube which then passes into the condensing cylinder R where it is shaped into a small coil and emerges at Z It then terminates in a little cup The latter becomes filled with condensed spent wash vapour A small saccharometer is kept floating therein so that the density of the aqueous portion of the spent wash can be observed Any appreciable quantity of spirit which might be present would so affect the density that incomplete exhaustion of the wash would be promptly indicated

The U shaped curves at the lower parts of the various pipes are made specially to prevent regurgitation

The type here described and illustrated is one of the simplest types of this pattern of still

86 *Method of cleaning patent stills* —Patent still apparatus can be cleaned by steaming or in the usual manner with hot water A method used in America is as follows —

> After long use distilling apparatus occasionally acquires a crust having a thickness up to ¾ inch, consisting of hardened mash, grease sand yeast cells, husks etc To remove this without taking the apparatus apart, the latter is filled with cold water After a short interval the water is drawn off, all outlets are opened and a copper pan filled with equal parts of alcohol and kerosene is inserted from the side and set on one of the vapour pipe caps The mixture is then lighted In three or four minutes the chamber becomes dry and hot and the crust so loose that it can be easily removed The process is repeated with each chamber, beginning at the lowest With a gallon of the mixture the largest apparatus can be cleaned in four hours

87 *Characteristics of patent still and pot still spirits* —Patent still spirits can be prepared so as to contain the maximum amount of alcohol obtainable by distillation alone Thus spirit can be obtained from a patent still which may contain as much as 97 per cent by volume of alcohol An efficient patent still removes some of the by products of alcohol altogether or reduces

the amounts of all very greatly The amounts of acids aldehydes, ethers and higher alcohols ("fusel oil") are very greatly reduced, while furfural in most cases is practically altogether removed A patent still spirit may thus be found to contain no acid or furfural, only traces of aldehydes small amounts of ethers and of higher alcohols

A pot still spirit always contains very appreciable amounts of acids, furfural and aldehydes, and the quantities of ethers and higher alcohols present in it are very much higher as a rule than in patent still spirits But no absolute rule can be laid down as patent stills greatly vary in efficiency, and experience at the Central Excise Laboratory clearly shows that some of the less efficient forms may even produce spirit not very different in composition to that made in good pot stills Again, a well made patent still spirit may be stored in previously used vats or casks and absorb from them definite amounts of acids, furfural, higher alcohols and ethers

88 *Flavouring of patent still spirits*—Many of the well known brands of whiskey, etc, consists of blends of patent and pot still spirit so arranged as to maintain a constant flavour the blender s being in the United Kingdom, nearly as important a branch of the spirit trade as that of the distiller An inferior class of spirits is made by mixing patent still spirits with essences and these may also be coloured in imitation of brandy whiskey, etc, with caramel or with coal tar or other dyes or by storage in casks

The flavouring essences used are known as essences of whiskey brandy, rum, gin, etc It is necessary that the quality of these colouring and flavouring agents should be controlled Cheap and very deleterious agents may be used at times and some of the allegations of deleterious quality which are so often made against cheap imported spirits have been traced to the employment of such deleterious agents

89 *Potable qualities of pot and patent still spirits*—As regards potable quality, pot still spirits contain the natural flavouring by products of spirit to a much greater extent than patent still spirits They are thus of a less artificial nature than patent still spirits which in many cases require to be flavoured and otherwise compounded in order to make them palatable Pure patent still spirits produced at the highest strengths practically taste of nothing but alcohol and water and are not, to the ordinary man s taste, palatable Sugar spirits retain such a distinctive flavour up to 40° or even 45° O P as to bear dilution to low strengths quite well, but 25° O P is a good strength to distil to when it is desired to obtain a strong sugar flavoured spirit If the distinctive flavour of *mahua* is to be retained sufficiently, distillation should not in general proceed to a higher strength than 30° O P. In India spirits are not blended to meet consumers' requirements to anything like so large an extent as in European countries

Good pot still spirit perhaps may, on general grounds, be preferred to patent still spirit as being essentially a naturally produced spirit and not an artificially compounded article But the proportions of natural by products ordinarily occurring in either pot or patent still spirits are present in such relatively small quantities as to make any real difference as regards their wholesomeness negligible in practice At the same time, it must not be forgotten that at any time pot still spirit may be produced under very un wholesome conditions due to faults or accidents in manufacture For ex ample such spirits made in India have been found at the Central Excise Laboratory to contain more than 12 times the maximum permissible limit adopted at the Laboratory for aldehydes, 25 times the permissible maxi mum for furfural and 30 times the permissible limit for acids There is much less danger of this with patent stills but even with these, the amount of aldehydes has in England through defects in manufacture risen to more than twice the permissible maximum Again it has been seen that noxious essences may be employed to compound patent still spirits So that control by Government is necessary in the interests of the public

90 *Keeping and carrying properties of spirits* — As regards storage and transit of spirit a strong spirit may usually be expected to keep or carry better than a weak spirit Further it is obviously more economical to trans port from distillery to bonded warehouse or other issuing agency a strong spirit which can later be diluted to any required bulk To transport weak spirit is to carry chiefly water Spirit of 60° U P strength has been found at the Central Excise Laboratory to be as low a strength as can ordinarily keep and carry well But carrying and keeping qualities depend on care in manufacture and cleanliness of spirit receptacles as well as on alcoholic strength Some pot stills can turn out (redistilled) spirit as high as 50° over proof but the average strength of the complete distillate under the best conditions seldom exceeds 25° O P and on the other hand some Indian patent stills (of inferior type or badly worked) turn out spirit not much over proof strength

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CHAPTER V.

By-products of Spirits

91 *The component parts of ordinary spirit* —Spirits consist almost entirely of ethylic alcohol and water along with which occur small amounts of by products or secondary constituents which serve the purpose of flavouring them according to their nature and amount, and these determine the quality

Ordinary or ethylic alcohol is thus by far the most important ingredient of alcoholic liquors Compared with it, the by-products are present in very minute quantities The latter may be considered in the following groups —

1 Higher alcohols,

2 Aldehydes, including furfural,

3 Ethers,

4 Acids,

5 Acetals, volatile alkaloids, and oils

92 *Higher alcohols*—The principal higher alcohols occurring in potable spirits are amyl, butyl and propyl Others, such as caproic or hexyl, heptyl, octyl, etc, occur in such minute amounts that they need not be considered for practical purposes These higher alcohols are the chief components of what is popularly known as fusel oil The term fusel oil comes from a German word *fusel* which means bad brandy as bad brandy was believed to be due to too much fusel oil being present Fusel oil when separated and analysed, is found to contain, besides higher alcohols, other substances such as ethers and volatile oils It is thus a very complex mixture Fusel oil is produced chiefly during fermentation These higher alcohols are so called because in general they have higher densities and boiling points and more complex chemical composition than ordinary or ethylic alcohol Small proportions of fusel oil are invariably present being normal products of fermentation and it is impossible to remove them entirely without destroying the potable character of spirit So that it is incorrect to talk of a potable spirit as being "quite free from fusel oil"

93 *Aldehydes*—When ordinary or ethylic alcohol is attacked by oxygen it is oxidised first of all into a different substance termed an aldehyde There are numerous aldehydes, in fact each variety of alcohol has its own particular aldehyde Thus the aldehyde of ordinary ethylic alcohol is termed acetic aldehyde or acetaldehyde Its name will be easily remembered from the fact that vinegar or acetic acid is the substance into which this aldehyde is next oxidised Amylic alcohol the chief constituent of the so called fusel oil, has its amylic aldehyde and propylic and butylic alcohol (also present in fusel oil) have their propylic and butylic aldehydes And so on with the other alcohols present in spirits There is another aldehyde which it has generally been customary to refer to separately in discussing alcoholic by products This is furfur aldehyde or, as it is usually more shortly termed furfural This is the aldehyde of furfur alcohol It is also chemically spoken of as pyromucic aldehyde, and it changes on further oxidation to pyromucic acid The aldehydes first referred to are produced during the course of fermentation, and distillation —from oxidation of

alcohol by various agencies Furfural, however, is chiefly produced by the action, during the course of distillation, of the hot acid, alcoholic liquid on certain vegetable fibres containing chemical ingredients suitable for its production Aldehydes are in Indian distilleries chiefly produced during fermentation Furfural is mainly formed during the course of distillation

94 *Ethers* —The combination of an alcohol with an acid forms an ether These are properly called esters or compound ethers As ethylic alcohol and its acid (acetic acid) are those chiefly present in spirits, the ether formed by their combination (acetic ether) is naturally the ether most commonly found From the acid derived from butylic alcohol in turn is obtained butyric ether, from the acid derived from amylic alcohol valeric ether, from the propionic acid derived from propyl alcohol, propionic ether, etc Ethers are formed during the course of both fermentation and distillation

95 *Acids* —The next group of by products is the acids These chiefly result from the further oxidation of aldehydes, but are also produced by the action of special acid forming germs which produce acetic acid, lactic acid, butyric acid and more rarely other acids according to the particular type of germ present or predominant Acids which occur in freshly distilled spirits are volatile acids Volatile acids partly distil over along with the alcohol in spirit manufacture Fixed acids cannot do so and are left behind in the still When fixed acids are found in a spirit they come from absorption of tannic or other organic or vegetable acids from the wood of the cask in which the spirit has been stored after distillation

96 *Acetals volatile alkaloids and oils* —The combination of an alcohol with an aldehyde forms a substance called acetal Such compounds are present in potable liquors usually in such very insignificant traces that they may be dismissed with the mere mention that they occur There are also sometimes formed in certain spirits volatile nitrogenous substances of the nature of alkaloids but only in very minute amounts They are in general more curious than important

Volatile oils also distil over and often give a characteristic odour to the spirit as in *mahua* spirits In this case they occur naturally in the *mahua* flowers But volatile oils are sometimes added by the distiller to flavour the spirit before or after distillation instances of such added oils are oil of aniseed peppermint, and cardamom

97 *By products are generally present in negligible quantities* —The foregoing by products are ordinarily present in relatively very small proportions Although most of them are very poisonous if separated out by themselves and given in sufficiently large amounts to a man or animal yet in the proportions in which they are usually found in spirits their action is quite harmless

98 *Physiological action of alcohol and its by products*—The effect of alcoholic liquors depends on their strength on the amount taken on the age and susceptibility to alcohol of the individual and on whether tolerance has or has not been established by the more or less frequent use of alcohol Its action is principally on the nervous system and this it to some extent affects differently in different people even when equal strengths and quantities have been drunk It acts in the early stages as a stimulant and later when a sufficient amount has been taken as a depressant and paralyser of nervous energy The higher alcohols (amyl butyl propyl) act like ethyl alcohol only more strongly They therefore tend to increase the action of ethyl alcohol when they are present in sufficient amount which is very seldom

Aldehydes and furfural have similar actions and in sufficient quantities add to the paralysing effect of alcohol on the nervous system These sub stances are moreover much more irritating to the stomach than is ethyl alcohol

Acids and ethers are the least harmful of the by products and can only harmfully modify the action of spirits usually to a very trivial extent On the other hand certain of the ethers of alcoholic liquors make them much more palatable and in this way tend to modify favourably the action of alcohol

The results of a special enquiry made in India into this question in 1905 06, which were fully confirmed later by the Royal Commission on Whiskey and other Potable Spirits which reported to the British Government in 1909, are summed up in the foregoing remarks to which the following may be added —

The action of relatively small quantities of by products found in even the worst samples of liquor analysed would appear to be unimportant and practically negligible Amounts of by products far exceeding those ever found in alcoholic liquors were administered with no appreciable effect Raw (new and unmatured) whiskey however contains irritating sub stances resembling creosote and for this reason is found to cause unpleasant symptoms which more matured whiskeys do not produce Again liquors like absinthe cause specially deleterious effects but this is due to the added wormwood oil and not to any naturally occurring alcoholic by products

99 *Cheap imported spirits*—Cheap imported spirits have long lain under the suspicion of being specially deleterious This however is not true of the average spirit of this nature Such spirits are made from alcohol highly purified by rectification in patent stills and then flavoured with spirits or essences of various kinds The risk in such types of spirits is the use of deleterious essences which are added in order to give them colour flavour and odour

100 *General precautions necessary to avoid impurities* —Apart from the question of essences, the chief precautions required in order to avoid impurities are care in manufacture and the prevention of addition of drugs or of other deleterious ingredients to the spirit In the majority of Indian distilleries every detail of the process needs improvement, *e g*, as regards cleanliness of stores, fermenting vessels and sheds, the use of proper fermenting vats, a sufficient water-supply, proper mashing in every particular, proper stirring of the wash during fermentation, regulation of temperature of fermentation and of acidity, a proper method of pitching with sound yeast, the avoidance of an unduly prolonged fermentation, straining off the solid matter of the wash before feeding the still, the avoidance of delay in distilling the wash on completion of fermentation, still-feeding by gravitation, and, generally, proper technical control of the whole process

The enquiry in 1905-06 into the quality of alcoholic liquors in India showed that usually furfural and acids are the only two kinds of by-products which tend to be present in too large amounts in country spirits The results of the investigations above referred to also proved that single or double distillation, or fire or steam heat, has no appreciable effect on acid or furfural production It was shown that those washes which contain the largest amounts of solid vegetable matter, such as *mahua*, *rice*, raisins, dates, and toddy, yielded most furfural, while spirits made from *gur*, *jaggri* molasses and other sugar residues gave least Patent-still spirits in India are usually made from *jaggri* or sugar-refuse bases This fact and the action of the patent-still itself account for the circumstance that furfural is least in amount or even absent altogether in such patent-still spirits

101 *Furfural control* —To avoid excessive proportions of furfural one or more of the following precautions should be adopted —

(1) The wash should be strained when being run into the still so as to remove solid vegetable matter Furfural is formed during distillation by the action of the hot acid liquor on vegetable fibres hence the necessity for straining these off, especially in the case of *mahua* in which the flowers are usually passed with the wash into the still, with the view of increasing the *mahua* flavour

(2) Over-firing of the still should be avoided, as furfural is produced more abundantly when the wash is over-heated, especially towards the end of distillation

(3) Automatic stirring apparatus should be used, especially with fire-heated *mahua* washes

(4) A doubler and rectifier should be fitted to the pot-still, as furfural, being a substance having a high boiling-point, is kept back by their action Care must, however, be taken to empty the

doubler after each distillation and to keep it and the rectifier clean

102 *Prevention of excessive acidity*—For the prevention of excessive acidity, proper fermentation, the avoidance of delay in distilling the completely fermented wash, proper firing of the still, and the use of a doubler and rectifier are the chief precautions to be observed in manufacture In the finished spirit, excessive acidity will tend to occur if the spirit is over-diluted with water or placed in dirty receptacles It may be again pointed out that a fairly well made spirit of as low a strength as 60° U P will keep and will bear carrying well, but badly made and dirtily stored spirits of much higher strength have been proved to do neither

The volatile acid which occurs in spirits is chiefly acetic acid and it is chiefly produced during fermentation, but to some slight extent also during the subsequent distillation The amount of acidity in Indian washes varies within large limits Some washes for instance have been found to contain 15 times as much acid as others and, when the varying time of fermentation in different distilleries is remembered, this is hardly surprising

103 *Control of aldehydes*—Aldehydes other than furfural are produced during fermentation and also during distillation Improvements and care throughout fermentation and distillation will generally act in the direction of lessening aldehyde formation The doubler and rectifier have less effect on aldehydes than on any of the other by-products The formation of aldehydes has been found to be much favoured by high temperature of the wash But high air temperature favours the evaporation of the more volatile aldehydes It thus often happens that crudely made pot-still spirits made during the cold weather in Indian distilleries contain more aldehydes than spirits made under the same conditions during the hot weather, as the escape by evaporation of the aldehydes is favoured by the high air temperature

104 *Prevention of excessive fusel oil production*—Fusel oil is, contrary to popular idea, of little practical importance in Indian liquors It is produced during fermentation chiefly, so that care as regards the details of fermentation is specially indicated The employment of a doubler and rectifier are particularly useful in keeping back the higher boiling point amyl and butyl alcohols, but have much less effect on the propyl alcohol, which passes over along with the ethyl alcohol, from which it is practically impossible completely to separate it

105 *Control of ether production*—Ethers are produced during fermentation and distillation General care in conducting these processes and the proper use of a doubler and rectifier will keep the ethers within proper limits

The same remark applies to other by products of less importance and less frequent occurrence, such as volatile alkaloids, acetal and volatile oils

106 *Copper contamination of spirits*—Serious contamination tends to occur from copper salts when the condensing worm is not carefully kept clean. As much as seven grains of copper per gallon have been found in country spirit The most serious cases of copper contamination occur in *mahua* spirit and this is due to the volatile fatty acid in *mahua* which distils over, chiefly towards the end of distillation, and is deposited in the worm Here it attacks the copper and forms a compound, a copper soap At the following distillation the alcoholic vapours and fluid dissolve some of the soap, thus contaminating the spirit

The fatty acid in question is itself harmless It is its combination with copper that makes it dangerous The fatty acid is solid at ordinary temperatures, and melts at about 55° C (=131° F) The copper soap it forms is insoluble in water but is soluble in alcohol especially if slightly acid as in country spirit It becomes fluid in boiling water Thus the fatty acid is much more easily liquefied than is the copper soap Hence it is best to deal with it before it has attacked the copper and the best means of doing so is that already described in Chapter IV Copper salts are not volatile and hence cannot distil over, but small quantities may pass into the receiver if "priming" occurs or through crude and unsuitable condensing apparatus The copper receiver is seldom the cause of contamination and, if kept clean cannot be The separation and redistillation of the first and last portion of the distillate is essential to the production of an uncontaminated liquor

Liquor may turn inky from contact with iron pipes or nails and wood—iron tannate being formed This is not poisonous, but such liquor needs to be redistilled to rid it of the coloration Zinc (derived from galvanised iron pipes or vessels) and lead (from water used to dilute spirits) may also cause spirit contamination

107 *Tests for impurities*—By products are not generally present in proportions sufficient to be injurious to health Nor, when they are, can they be detected by any such simple tests as could safely be applied by Excise officers

Control of quality generally must therefore be exercised by the periodical submission of samples for analysis An exception to the rule is made, however, in the case of copper salts In this case a permissible limit of a quarter of a grain per gallon of spirit as it leaves the still (provided that it is reduced to 10° U P if it exceeds that strength) has been prescribed and the following procedure for detecting it has been laid down

108 *The C E L test for copper*—Freshly distilled spirit should be tested, as casked or vatted spirits are less sensitive to the test Two similar

conical test glasses (each holding about six ounces) should be equally filled nearly to the top with the sample under test. Three drops of ferrocyanide of potassium solution* should then be added to one glass only and the contents stirred up with a glass rod. If there is the slightest production of a reddish or pink colour in the contents of the glass so treated, when the two glasses are placed side by side on a sheet of white paper and observed from above, then the sample contains copper in excess of the limit of a quarter of a grain per gallon. Comparison in this way with the original spirit (i.e., untreated with the ferrocyanide solution) is essential. If a blue or green colour results, iron is present and the sample should be sent to a laboratory for analysis, as no opinion as to the amount of copper salts can then be formed by the ferrocyanide test alone. It should be specially noted that the spirit must be diluted to 10° U.P. or less, as higher strength spirits than this tend to interfere with the test by precipitating the ferrocyanide.

109. *Flavouring and colouring agents.*—The following ingredients used in making spiced liquors are harmless:—Ginger, nutmeg, gum acacia, saffron *keora* (*Pandanus odoratissimus*), turmeric, fruit of *Helicteres Isora*, seeds of *Nelumbium speciosum* (a species of water lily), catechu, fennel, aniseed, cardamom, coriander, orange, *mundi*, *nim*, peppermint, mango, *khas khas* sweet lemon and rose. Red and black peppers are added with a view to increase thirst and this practice should be forbidden. Of colouring agents caramel is the most satisfactory. The following are a few examples of others that have been tested:—

(1) Night jasmine flowers (*harsinghar*, *shieuli*).—These are permissible. A rough test for detecting whether or not this agent has been used is to add a small quantity of hydrochloric or sulphuric acid to the liquor. This addition should produce no change in liquor coloured by night jasmine. If, however, a red colour results, some other colouring agent than night jasmine has been used, probably an aniline dye.

(2) The *tesu* flower is also a harmless colouring agent.

(3) So also is saffron, which is occasionally used instead of caramel.

(4) The aniline dye,† Diphenylamine orange (also called Tropæoline 00 or Orange IV,) rather resembles the colour produced by night jasmine. It is, however, a poisonous dye and its use in any proportions should be forbidden.

* As much powdered ferrocyanide crystals as will be heaped on a two anna piece added to half an ounce of pure water will make a solution of sufficient strength. The solution should be kept in the dark when not in use. When it turns a deep yellow colour instead of pale lemon it should be thrown away and a fresh solution prepared. The ferrocyanide crystals should

(5) "Phosphine" is another dye used for colouring liquor and su
Its use in the case of spirit is permissible, as it has been fo
to be non poisonous in the proportions used usually abo
grain per imperial quart of liquor

110 *Composition of flavouring essences*—*Whiskey essence* may be m of fusel oil, especially of the higher fractions, dissolved in strong alco Oil of birch is also used *Rum essence* is often made of ethyl formate, wl possesses an odour of peach kernels Ethyl butyrate is another ether frequ ly used as a rum essence and is often made for this purpose by distil saponified butter with alcohol and sulphuric acid Rum owes its characteri flavour to ethyl butyrate and formate, hence the employment of these essences Prune juice is also used as a flavouring constituent Oil of ca has been found to be the chief ingredient of other rum essences

For *brandy essence*, ethyl pelargonate (œnanthic ether) is largely us as also is acetate of ethyl Nitrite of ethyl is occasionally used, but is a permissible ingredient Oils of cloves, cassia, bitter almonds, galls, spice and oakbark are also occasionally employed Imitation brandy made at times by distilling plain spirit with argol, prunes and a small amo of real cognac and then adding tannin and colouring with caramel "Cog oil is also employed to flavour imitation brandies

Gin essence is usually prepared from juniper oil or berries Turpenti almond cake, coriander, cardamom red pepper, grains of paradise, orris a angelica roots are also used as flavouring agents

No chemical flavouring and colouring agents which it is proposed to u for making so called "foreign" liquors from plain spirits should be allow to be employed until samples have been sent for analysis and the proportic in which they may be used, if at all laid down

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CHAPTER VI.

Arrangement of a Distillery.

111 *Distillery arrangements dealt with under the substantive law in England*- The proper arrangement of the compartments and vessels of a distillery is matter of the first importance from the point of view of the revenue as well of the distiller, so much so that in the United Kingdom the provisions regar ing this matter form part of the substantive law, *vide* Schedule I to the Spiri Act 1880, on which the following instructions are in a great measure base

112 *The simplest form of arrangement described*—One main object the arrangements being to secure that the spirit shall pass through its enti course in closed pipes, it is convenient as well as economical to make use

BLOCK PLAN

SHEWING

Arrangement of a distillery

Elevated water Cistern

Cistern for collection of wash

Pump

Wash charger

Fents receiver

Spirit receiver

Storage Vats

Safe

Worm tub

Still

Reduction Vat

Fermenting Vats

Drain

Drain

Issue Vats

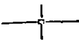
Store for materials

Gate

Excise Office

Distiller's Office

Guard room

Pipes with Stop-cocks shewn thus 

the force of gravitation and to build either on a hillside or in several storeys In the ordinary country distilleries, however, to which this chapter particularly relates, it is not usual to build in more than one storey and it will be sufficient for the present purpose to consider a single storey building as illustrated on the opposite page This consists as will be observed in a series of compartments on the inner side of a secure wall the first for storage of materials, the second for preparation of wash the third for charging of stills, the fourth for distillation, the fifth for spirit receivers and the sixth for storage, reduction and issues It will be convenient to consider these in order

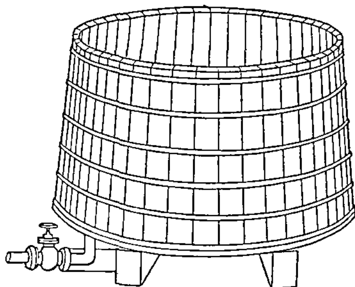
113 *The outer wall* —The outer wall should be of brick or stone and high and secure No lean to buildings on the outer side should be allowed All openings in it, *e g*, windows ventilators or the drain for the issue of spent wash, should be covered with wire netting of square mesh the apertures of which do not exceed one quarter of an inch so that no vessel can be passed in or out This should be riveted on the inside to the window frames All windows and ventilators should in addition be secured by malleable iron bars at least three fourths of an inch in diameter and not more than four inches apart fixed deeply in the brick or stone work Windows on the ground floor should also be secured by inside shutters having strong hinges and a cross bar

A single pair of high and secure gates for the admission of materials and issue of spirit is generally sufficient The gates must be so constructed that when shut they cannot be lifted off the hinges On the two sides of these guard houses may be placed outside and offices for the Excise officer and the distiller inside The doors must have proper fastenings for securing them with revenue locks These fastenings whether of the ordinary hasp or other formation should be attached to the doors by screw bolts riveted over nuts on the inside The hinges should be attached to the doors and door frames by bolts riveted on the inside and all hinge joints should be formed by welding and not by ordinary riveted pins

114 *The store for materials* —In the store for materials a pukka floor and proper walls and roof are essential The doors and windows should be covered with wire-gauze frames to keep flies from the *mahua*, sugar, etc, stored within The doors should be fitted with weight or spring attachments so that they cannot be left open between the removals of material The windows should have the gauze frames fixed so that, if glass windows are also used they can be opened without disturbing the gauze protectors Where escape holes for drainings are necessary, they should be fitted with strong and securely cemented iron gratings so as to exclude rats and other vermin

115 *The fermentation room* —The fermentation room also should be cemented or closely paved under foot so that any wash that is spilt may be cleaned up at once and not remain to form a breeding ground for wild yeasts

and acid-forming germs which tend to infect subsequent washes through the air Ample provision should be made for ventilation and water supply. The vats should be of oak or other hard wood, not liable to warp, split, or



leak, or of cement, not of metal, which is liable to corrode Fermentation vats are usually somewhat deeper than they are broad and the foot is broader than the top, but where solid *mahua* is passed into the wash it is useful to have the top as wide or wider than the foot so as to expose more of the *mahua* to the action of the water The use of earthenware pots and small casks should be discouraged Each vat may be covered with a lid freely perforated with holes so as to allow of the escape of gas and the access of air as well as to exclude flies, etc The vats should be set in a regular order above the main pipe or trough by which the wash is conveyed to the wash charger The following are the provisions of the Spirits Act in this connection —

There must be fixed in every fermenting back to the satisfaction of the proper officer, a discharge cock or plug and plug hole through which the wash in the back may be conveyed by a main pipe or open trough into the jack back or wash charger

[illegible]

this pipe must not open into the back

Except as aforesaid and except the pipe for conveying wort into the fermenting back from the coolers and a sewer cock or plug for carrying off the water wherewith the back is cleansed there must not be any pipe or conveyance entering into or passing out of the back *

* Spirits Act, 1880, First Schedule, Third Part.

116 *The wash-charger*—In some distilleries an intermediate vessel known as a wash-charger is used Into this are run the contents of different fermentation vats until a sufficient charge for the still has been obtained Where distillation is continuous, as in a patent still, a wash-charger is almost invariably used From the wash-charger the wash is carried by a closed pipe direct to the still The wash-charger's capacity should be not less than half that of the largest fermenting vat It may be connected with the feints receiver by means of a close pump or metal pipe, through which impure spirits may be returned to the still for redistillation

117 *The still*—The vessels should be arranged, if possible, so that the wash may pass by gravitation into the still and the spirit may pass by gravitation into the receivers The condensing tub should be fed by a constant supply of water as cool as is obtainable and the supply tank should be high enough to allow of this The following orders regarding still fittings are extracted from the "Instructions for Surveying Distilleries" *—

Stills may be of any form or construction the distiller may think proper, but there must be no openings into them except those in connection with the respective chargers, and an air cock or valve upon the breast or head The external orifice of the air valve must be so constructed and covered by a perforated metal plate, that it would be impracticable by that means either to introduce wash or to abstract spirits, or to convey away spirit vapour for condensation elsewhere When common stills are heated by means of steam, no objection is to be made to perforation in the steam pipe within the still so that the steam may mix with the wash or low wines to be distilled, provided the pipe, before it enters the still, is at such a level that the fluid in the still cannot flow into the boiler when the pressure of the steam is withdrawn The cock on the steam pipe, near the still, must be secured with a working fastening when the still is at work, and with a close fastening during the brewing period A working fastening is one that will admit of the key being turned but not of its being withdrawn from its proper position in the cock The mandoor in common stills must be provided with proper fastenings and kept locked, except when the still is open, under notice, for cleansing or repair Every ordinary still must have a discharge cock, easily accessible to the officer, and not more than three feet distant from the body of the still, this cock is to be kept locked when the still is not at work

* Paragraphs 54 and 55.

118 *The safe or sampling apparatus* —There should be placed between every still and the receiver or receivers into which it discharges a glass safe furnished with a hydrometer capable of showing the strength of liquor down to water so that both the quantity and strength of the spirits which are running will at any moment be visible to the operator If desired, a sampling apparatus may be used instead, provided that it is so constructed that for every sample drawn off an equal quantity shall be discharged into a closed and locked receiver, and that the samples shall be produced to the officer and shall be found by him to agree in measurement and strength with the corresponding quantity so discharged into such receiver and shall be passed by him into store

A useful pattern of safe is one made with thick glass sides firmly riveted or cemented into stout metal supports The front face of this box is made to open and is fitted securely with a hasp and locked with Excise and distiller s padlocks An arrangement for allowing vapour to escape without risk of abstraction of spirit is required This is often a small pipe inserted between the worm and the safe the end of which is closed with a fixed plate perforated with small holes through which the vapour escapes It should be noted that if the safe clouds with vapour it is evident that the arrangements for condensation and cooling of the liquor are inadequate Whatever the pattern of safe or sampling apparatus used it must be so constructed that, when locked, spirits cannot be abstracted therefrom by the introduction of a pipe or syphon, by causing to overflow or by other means

119 *Receivers* —The Receiver of a pot still should be large enough to hold all that the still can discharge at one distillation whilst a patent still must be provided with two receivers to ensure continuous working and purity of product They may be of wood, cement, or least preferably, of iron Copper should never be used They should be fixed and immoveable, so constructed as to be quite secure from attempts at abstraction of spirit and so as to be able to be thoroughly cleaned out periodically, and so placed that they can easily be examined and the fact that they have not been tampered with readily ascertained If the first extract of a pot still distillation is to be issued for sale it is essential that a feints receiver should be provided for the fore shots and tailings so that the middle portion of the distillate may be separated from them in another vessel and may alone pass into consumption If the whole distillate is to be redistilled a second vessel is not so necessary, but it is convenient in this case also to separate the feints from the finished spirit

When two receivers are fitted to the same still arrangements should be made so that the distillers may be able to divide the spirits discharged from the still into different lots according to their strength or quality, without

requiring the presence of the officer to unlock cocks or to empty a receiver This may be easily arranged for by making the end of the worm lock into a pipe from which branch pipes will lead into different receivers

Every spirit receiver must be connected with the safe at the end of the worm by means of a close metal pipe, externally visible throughout its whole length, and so placed that the spirits shall run directly from the safe to the receiver, there must also be a pump or a proper discharge cock fixed in the receiver for drawing off the spirits and connected therewith a close metal pipe, externally visible throughout its whole length, for conveying the spirits directly from the receiver to the spirit store or back to the charger

The entry and exit pipes should be fitted with cocks which must be locked by the Excise officer and, if desired, by the distiller also The cock on the charging pipe must be shut and locked whenever that on the discharge pipe is open and *vice versâ*, except when both are required to be open simultaneously for cleaning and repairs in which case either the whole apparatus must be disengaged from the still itself and be so secured and locked that it cannot be used again until the officer has removed the lock or the still itself must be locked up so that it cannot be used When spirits run from the receiver into the warehouse, the discharge cock of the receiver should be frequently tested to see that it does not permit any leakage when shut, by shutting for half an hour or longer the cocks at the vats while spirits are collecting in the receiver, and by ascertaining whether any accumulation takes place in the pipe

120 *Disposal of spent wash*—The disposal of the spent wash is sometimes a cause of difficulty So far as distillery arrangements are concerned the essential is, once the officer has satisfied himself that it is exhausted, that it should be passed out of the distillery premises as soon as possible This is best arranged by letting it run out by gravitation along a shallow floor channel, well cemented and swept clean after each operation If it is desired to keep some of the spent wash for use in later operations it should be pumped into a covered vessel kept for the purpose Underground spent wash tanks should never be allowed as they get into a very filthy state and poison the air of the fermentation shed

121 *Spirit store*—The spirit having passed from the receiver into a storage vat it remains to consider the arrangements for storage, reduction and issues In a small distillery these processes are ordinarily conducted in a single room about which it is only necessary to remark that it must be protected by secure doors and well lighted and must have all apertures covered with wire gauze It is commonly convenient to arrange the vats along one side at such a height that a cask can conveniently be placed underneath and to carry the spirit and water pipes overhead The vats should be divided into three sets for storage, reduction and issue The products of distillation

are passed direct from the receiver into the storage vats and one may be added to another, even though they are of different strengths, if there is no storage vat empty When it is proposed to reduce stored spirit by the addition of water to one of the fixed issue strengths the spirit should be passed into a vat set aside for the purpose, or at any rate into an empty vat, for water to be added to it in accordance with the reduction tables When the desired result has been attained the product should be passed into an issue vat set apart for the issues of spirit of the strength in question

122 *Spirit vats* —All spirit vats should be closed covered vessels properly secured and connected with the receivers or with one another by pipes through which the spirit is run by gravitation or pumped The best material for vats is wood, but cement may also be used Metal is least suitable and copper should never be employed for this purpose Vats should be placed on a secure foundation at such a distance from the floor of the store room as to enable casks or other receptacles to be placed under their escape pipes They should have a clear space all round them so as to be readily inspected and easily got at in case of leakage, etc They may be painted, but if the staves are plugged, a seal should be put over the plug The only openings allowed should be the pipe connection through which the vat is filled, the manhole at the top and the cock at the bottom All these must be securely locked with revenue locks The vat and the discharge cock should be so set that the whole of the contents of the vat can be drained out through the cock

123 *Marking of rooms, vessels and casks* —The following are the provisions of the Spirits Act, 1880, in respect of the marking of rooms, vessels and casks —

Every distiller must cause to be legibly painted with oil colour and must keep so painted on some conspicuous part of every vessel or utensil intended to be used by him in his business and of the outside of the door of every room and place wherein any part of his business is to be carried on or any spirits are to be kept, the name of the vessel, utensil room or place according to the purpose for which it is intended

Where more than one vessel utensil room or place is used for the same purpose all such vessels utensils rooms or places must be marked by progressive numbers

A plan of the distillery showing the position of all rooms and fixed vessels should be taken from the distiller and brought up to date whenever any change is made An account should also be kept up to date of all vessels and casks When a distiller wishes to disturb a vessel or its fittings in any way he should obtain sanction through the officer in charge in order that the vessel may be re gauged before it is again used

* Spirits Act, 1880 First Schedule, Ninth and Tenth Parts

124 *Pipes for conveyance of wash and spirit*—All conveyance of wash or spirit should be by pipe and not by bucket or cask Pumping or running by gravitation should be employed Thus the wash should be piped to the still and spirit from the receiver to the storage vats For temporary attachments rubber hose wired outside is perhaps the cleanest and best to use All pipes except those exclusively for discharge of spent wash or water should be visible throughout their entire length so as to be easily inspected or reached in case of leakage, etc Where a pipe has to pass through a wall the opening should be carefully cemented all round, or the opening should be grated and the pipe made to pass through the centre of the grating It will be found a great convenience and saving of expense to have pipes flanged and in comparatively short lengths so that they can easily be removed for examination The flanges should be riveted together and sealed with a revenue seal The ends of pipes required to connect the several vessels and utensils must be fastened to the utensils by soldering or by riveting

Under the Spirits Act of 1880 every pipe must be painted with a distinctive colour indicating its contents Convenient colours for this purpose in India are for spirit red, for wash green for feints brown and for spent wash yellow The officer in charge of the distillery should be held responsible for the proper painting of such pipes and for keeping them brightly painted Blind ends of fixed pipes should not be allowed The pipes should end in an elbow where they have their last outlet Where pipes must be left open in the absence of an officer, they should be stopped with a bung or plug and taped and sealed by the officer in charge

125 *Construction of cocks and fastenings*—Every cock kept or used by a distiller should be constructed in such manner as the Commissioner of Excise may from time to time direct The use of a rack or any other description of cock upon water pipes wash backs wash chargers, or stills may, however be allowed provided such cock, when shut, can be properly secured by a revenue lock, but, upon receivers and the pipes connected therewith, and upon pipes through which feints or spirits pass, the ordinary turning cock should be used The plug or key of such cock should not be riveted in, but must be so made that it can be taken out by an officer for examination, and it must be legibly marked to show when the cock is shut or open

Fastenings must be provided and maintained by the distiller for securing the trap doors of the chargers and receivers, the check dipping holes in the spirit receiver, and the cocks, plugs, pumps, vessels, and utensils required to be secured, and when it is necessary for the distiller's operations that cocks upon close pipes must be left open when no officer is present, working fastenings must be provided for such cocks The fastening should be constructed

as much as possible in one piece When hinges in them are necessary, the hinges must be formed by welded joints, and not by riveted pins, if part of any fastening is attached to a vessel or utensil, it must be by rivets and not by screws The fastenings for cocks must fit so closely as not to admit of any cock being partially turned or opened, or the plug or key lifted up or taken out, after the fastening is applied Chain fastenings should not be used except in cases where it would be impracticable to apply those of any other description

126 *Revenue locks*—For securing the cocks and fastenings above referred to a special pattern of revenue lock is employed in England which is so made that it cannot be opened without tearing a label which has been shut up in the lock On the label is entered the time at which it is attached, and the torn label is pasted after removal against the counterfoil so that it can be readily checked with the entries in the officer's diary The following instructions should be observed in use of these locks when they are supplied —

An account of all locks received in the distillery must be kept in its store register

Every lock in use or on a staple in the distillery must be carefully labelled immediately on being locked

When locks are neither in use nor on a staple, they must be kept in the possession of an officer or secured in the strong box

Should it happen at any time that a lock cannot be opened in the usual manner it is not to be picked or forced, but must be removed by cutting through the fastening

In the construction of fastenings care should be taken that the locks are not placed in such positions as to be constantly exposed to wet or injury When Excise locks have to be used in places where they are exposed to weather or corrosion by fumes or splashing with acid used for cleansing purposes a loose fitting tin guard should be employed

Before detaching a label from the book, the officer in charge must write upon both label and counterpart the date, hour and minute, with his initials, and, over the words printed in the middle, the initials of the name of the vessel or fastening for which the label is to be used

Before opening any lock the officer in charge must ascertain that the label is perfect When it is taken out of the lock the date, minute, and officer's initials should be written on the label and counterpart, and the label attached to its proper place in the book

No lock, key or label must under any pretext be allowed to pass into the hands of a trader or his servant, or of any other person whatever, not authorised by the Commissioner of Excise to inspect and examine it

127 *Course of wash, low wines, feints, and spirits*—The following extract from the English law sums up the course of the liquids passing through the pipes in a distillery arranged as above indicated —

All wash must be fermented in the fermenting backs and thence conveyed directly into the wash charger, and thence into the still for distillation

All low wines feints and spirits running from the worm of the still must run thence directly into the safe at the end of the worm

All low wines must be conveyed directly from the safe into the low wines receiver and thence directly into the low wines and feints charger and thence directly into the low wines still for re distillation

All spirits must be conveyed directly from the safe into the feints receiver or spirit receiver

All spirits conveyed into the feints receiver must be conveyed thence directly into the low wines and feints charger or wash charger or intermediate still charger and thence directly into the still for re distillation

No spirits conveyed into the spirit receiver may be re distilled or may be removed therefrom except into the distiller s spirit stores

All spirits distilled in the distillery must after the officer has taken an account of their quantity and strength be forthwith conveyed through a close metal pipe from the spirit receiver into the store cask or vat in the spirit store

Except after notice to or in the presence of an officer access may not be had to the end of the worm of any still or to any low wines feints or spirits from the time of the extraction or distillation thereof in the still until they are taken account of by the officer in the proper receiver or to any spirits in a store cask or vat *

128 *Checks afforded by these arrangements*—It will be observed that under these arrangements the officer has several checks on the outturn which he may test one against the other Taking these in serial order —

The materials are weighed out of a locked store and passed to gauged fermenting vats here the attenuation of the wash is noted when it is complete a given quantity of wash is run into a still of known capacity, the produce passes by locked pipes into a receiver where an account is taken of it, it is passed out generally before a fresh distillation supervenes, into a storage cask and an account taken again, thence a given quantity is passed out for reduction and account taken again the reduced liquor passes into an issue vat and is added to the account of liquor of the same strength and when it is finally issued a last account is taken An officer who wishes to satisfy himself that no fraud is going on can check the account of quantity issued against three other accounts viz, those of outturn, production and quantity issued for reduction Thus if he takes a given period, he knows the opening and closing balances, he knows the quantity of materials issued, and their average spirit yield and so can deduce the quantity that should have been outturned, he can check this against the quantity that was outturned

* Spirits Act, 1880 First Schedule Eleventh Part

according to the receiver record, he can trace this into the store, thence he gets a new set of checks, *viz*, of issues from store for blending against issues of blended liquor In course of time it is possible that the English system of raising a presumptive charge on the attenuation of the wash may be worked up to

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CHAPTER VII.

Proving and the use of the Hydrometer.

129 *Stages at which proving is necessary*—The hydrometer is the instrument most commonly used in Excise operations and is employed for the purpose of proving the strength of alcoholic liquors This should be done (1) while distillation is proceeding by means of a hydrometer in the safe in order to ascertain the strength at which the spirit is running and to know when all the alcohol in the wash is exhausted, (2) as soon as each distillation is completed in order that, with the aid of a gauge of the quantity, the number of proof gallons distilled may be reckoned, (3) a similar check should be made for a similar reason on each occasion of transfer of liquor from one vessel to another, and (4) all liquor issued must be carefully gauged and proved before issue and, if it is to be compounded, before any substance is mixed with it

130 *Description of the hydrometer*—The hydrometer enables one to reckon alcoholic strength by showing the density or specific gravity of the spirit in which it is floated

131 *Specific gravity explained*—By specific gravity or density is meant the relative weight of equal bulks of different substances This is expressed in relation to a standard substance, pure (distilled) water at a fixed temperature being taken for this purpose The specific gravity of a liquid is the relation which its weight bears to the weight of an equal bulk of pure water The specific gravity of water is thus taken as 1 and the specific gravity of alcohol has been found to be 794 Any mixture of the two has a specific gravity lying between these two figures, and tables have been constructed giving the amount of alcohol corresponding to all intermediate specific gravities

All substances which are dissolved in water alter its specific gravity Sugar or salt increases it (*see* paragraph 57), but alcohol or any other substance lighter than water lessens it Substances which are merely suspended and not actually dissolved do not alter the specific gravity of the fluid *

* Suspended matter however affects the reading of a floating instrument Thus a wash should be allowed to settle somewhat before being tested with the saccharometer whilst a turbid spirit sample must be allowed to clear completely by settlement or if necessary be filtered, before it is proved with the Sikes hydrometer

The specific gravity of a fluid is measured by various means, *e g*, by a hydrostatic balance, or by a specific gravity flask termed a pyknometer, but the means used in ordinary Excise or Customs work is the hydrometer The pyknometer can only be employed in a laboratory where a delicate balance and other requisites are available The hydrometer used for Revenue work in India is that of Sikes It is made of glass or of brass

132 *Description of Sikes s glass hydrometer*—Sikes's glass hydrometer consists of several distinct parts or spindles each of which has a large empty bulb, below which is a small bulb containing quicksilver (metallic mercury) The object of this latter is to make the hydrometer float in an upright position when placed in a liquid of suitable density Above the larger bulb is a narrow shaft or stem on which are marked numbered divisions and sub divisions Each of these divisions is termed a hydrometer or stem degree, and the sub divisions indicate fifths of a hydrometer degree The ordinary glass Sikes s hydrometer consists of five such parts or spindles marked respectively 0 to 20, 20 to 40 40 to 60 60 to 80 and 80 to 100 When proving the strength of a liquid the spindles which will float properly in it is chosen The other spindles will either sink to the foot of the vessel or float with the scale entirely above the liquid The appropriate spindle is read at the point where the surface of the liquid cuts its graduated upper portion The depth of immersion in the liquid is thus the guide to the alcoholic strength of the liquor as shown by its density

133 *Correction for temperature*—The temperature of the liquor is most important Liquids expand when heated and contract when cooled and so their specific gravities are increased by cold and lessened by heat If, for example, this matter of the liquid's temperature were to be neglected a spirit tested in the cool of the early morning would appear to have increased in strength when re tested in the heat of midday

The temperature of the hydrometer itself must not be neglected If a spindle be placed in a liquor cooler than itself it will tend to rise or fall and must therefore be left in the liquor until it has had time to become of the same temperature as the liquid Otherwise a hydrometer spindle which was warmer than the liquor in which it was placed would show a less alcoholic strength than it ought to do Sikes's hydrometer was originally graduated at 51° Fahr That is therefore the temperature at which Sikes's hydrometer has been constructed to give exact indications But to enable liquors to be proved at all ordinary temperatures, tables have been constructed (Sikes's Tables) which show directly the spirit strength corresponding to any stem-reading at any temperature between 40° and 100° F So that, by taking the liquor s temperature by means of the thermometer and looking up the tables at the temperature shown and then observing the reading of the hydrometer, the alcoholic strength of the liquor can at once be read off

134 *Special light spindle for proving high strength spirits at high temperatures* —The highest strength readable at 40° F by the ordinary 0—20 Sikes's spindle is 70 5 O P, whilst at 100° F the highest strength readable is 57 2 O P It will thus be seen that high strength spirits cannot be read at certain temperatures by the ordinary 5 part instruments Hence a special light hydrometer spindle made of glass is provided for testing high strength spirits at high temperatures This is known as the A or light Sikes's spindle The A spindle recommended for use is graduated like other spindles in 20 degrees each of which is sub divided into fifths The value of these readings at different temperatures is given in the corrected Sikes's table A spindles are widely in use, however, which carry only 10 degrees on their scale and with these a separate set of tables is supplied These tables, being uncorrected, should not now be used To the reading of such a spindle 10 should be added and the figure thus obtained looked up in the corrected Sikes s tables under the heading 'A'

135 *Direct reading hydrometers* —The glass Sikes's hydrometer with five spindles is used in distilleries and warehouses for proving spirits for duty Glass hydrometers of much less delicacy can be used for district and shop visiting work and these are often of the type known as "direct-reading" That is to say they are graduated so as to read in proof degrees (not hydrometer degrees) at a fixed temperature and a card is used with them which shows the correction to be made at temperatures other than that at which the hydrometers are adjusted These instruments may be graduated on one spindle so as to cover all ranges of strengths likely to be met with, or a two part instrument may be supplied with larger graduations and hence likely to be more accurate

136 *Reasons why glass hydrometers are to be preferred* —Glass hydrometers are preferable to brass hydrometers, especially for use in India, because the latter tend rapidly to become inaccurate, as the acid spirits corrode their surfaces and thus make them lighter than they should be Brass instruments are also more easily spoilt by being dented by blows or by being put away after use without having been properly washed in clean water and dried Again brass instruments are more easily tampered with than are those made of glass Glass instruments are, in spite of being more fragile than brass, cheaper to use in the long run besides being much cheaper to buy in the first instance It is obviously better that a glass spindle should be broken than that the same force should produce a dent on the bulb of a brass instrument and cause it to give unnoticed wrong indications

137 *Sikes s brass hydrometers* —The brass Sikes's hydrometer consists of a hollow bulb into which fits an upper shaft graduated from 0 to 10, each division of which is sub divided into five parts, each of which is thus one fifth of a stem degree To the under surface of the bulb is attached a conical stem which ends in a small loaded bulb which keeps the instrument's weight low enough to enable it to float in an upright position To this lower stem can be attached a series of graduated weights numbered from 10 to 90

Each weight represents the number of stem divisions indicated by its number This device renders it possible to have only one spindle and this of a convenient length If no weights were used, the single spindle would have to be inconveniently long Each weight commences where the preceding one leaves off Thus the 10 weight when floating at 10 is the same as the 20 weight floating at 0, and so forth To read the instrument, the weight gives the tens, the stem divisions the units, and the stem sub divisions the decimals

138 *Types of instruments most suitable for Indian conditions*—Five-part glass Sikes's hydrometers are required for distillery and bonded warehouse work A three part glass hydrometer (0—33, 33—66, 66—100) has also been used in one of the larger Provinces, but these spindles are less easily read and do not give such close indications as the five-part instrument

For shop visiting and district work one part glass hydrometers are largely used They are direct reading and are usually graduated from proof to 60° U P and in some cases to 70° U P They are usually standardised at 85° Fahr and a special correction table has been constructed for use with these instruments Where, as in one large Province, the range required is from 10° U P to 90° U P, two stout glass Sikes s spindles (33—66° and 66—100°) are most suitable for employment The brass Sikes s hydrometer should never be used in India to prove spirit for duty purposes In district and shop work the latter is less objectionable, but glass should always be pre ferred where possible Glass hydrometers with hollow stems open at the top, should not be used, as they tend to give misleading results unless special precautions involving delay, are taken They have other defects which make their use undesirable

139 *Method of taking samples*—Before an account is taken of spirit in any gauged vessel, all inlets and outlets should be locked The dip should then be taken and the contents of the vessel thoroughly stirred before withdrawing a sample for proving The amount of spirit taken for test should be sufficient to fill the hydrometer trial glass to within two inches of its top After the strength of the spirit has been proved, the sample should be re turned to the bulk from which it was taken

140 *Reading the hydrometer stem*—In taking a reading it is necessary, firstly, thoroughly to stir up the liquor so as to mix layers of different temperatures and densities, secondly, to give time for the mercury in the thermometer to come to rest, thirdly, to make sure that no air bubbles have collected on the hydrometer's surface

When the hydrometer has been immersed to the scale top and is floating at rest in the liquid, it should be read as follows —

(a) The observer should first place his eye so as to see just below the surface of the liquid in the trial glass

(b) He will then note that about one stem division is hidden by the surface layer of the liquid It is the lower edge of this surface layer (*meniscus*) which is to be read where it cuts the stem

(c) The stem is graduated from above downwards and must always be read in this direction Particular care must be taken as to this for, if read from below upwards, a serious error will result

(d) In dark coloured or cloudy liquids the lower edge of the *menis cus* cannot be seen so that in such cases the stem is read from the top of the stem downwards to the surface of the liquid and one sub division (for the *meniscus*) is then added Glass hydrometer jars (not metal vessels) should invariably be used in proving spirit

141 *Directions for use of Sikes's glass hydrometer with the corrected Sikes s tables* —The following directions are for use with the official tables —

Having poured a sample of the spirits intended to be proved into the trial glass, ascertain the temperature of the fluid by immersing the thermometer therein Stir the sample, and wait till the mercury becomes stationary. The degree shown on the thermometer scale is the temperature of the spirits. The various degrees of temperature are indicated at the top of each page, commencing with 40° and ending with 100° of Fahrenheit s thermometer. Open the book at the temperature indicated, and select the spindle likely to be required Immerse it in the spirit and press it down to the top mark on the scale If the proper spindle has been selected, it will float at some division on the stem, this is "the indication" Opposite this indication in the table will be found the strength of the spirit

Examples —

(a) If the hydrometer spindle 20 to 40 sinks to 28 0 (*i e*, indication 28) with a temperature of 40°, the strength found in the tables under that temperature at 28 will be found to be 46 3 over proof.

(b) If, again, at temperature 51° the hydrometer spindle 40 to 60 floats so as to indicate 43 0 divisions on the stem, then opposite the indication 43 under temperature 51° will be found the strength 25 3 over proof

(c) At temperature 60°, indication 69 2, the strength will be found to be 16 7 under proof

Each sub division of the hydrometer stem corresponds to 0 2 per cent. of the whole scale (apart from the portion termed A)

The slide rule and comparative rule as hitherto supplied with the uncorrected Sikes s tables should not now be employed

142 *Limits of accuracy*—To save expenditure of time on calculations which are apt to be more elaborate than accurate it may be noted that the following are the limits of accuracy for ordinary Excise work —

Thermometer readings to one degree hydrometer readings to one fifth degree, proof strength to one tenth degree as given in Sikes s tables, bulk gallons as found by the dip but in no case to more than one place of decimals

In reducing bulk gallons to proof the result should again be worked out to one place of decimals

In Customs calculations even less exactitude is possible because of the margin of error that has to be allowed for in the gauging of vessels of various shapes In this case it is ordinarily sufficient to work out strength to the nearest degree reckoning 5 and upwards as equal to 1

143 *Specific gravity balls*—In some large distilleries in place of using a hydrometer at the safe a number of beads or balls each having a fixed specific gravity marked on it are placed in the fluid in which some float and some sink The gravity is shown by the bead which at any moment rises or falls in the liquid These beads give a rough indication of the spirit strength during the course of manufacture They should never of course be employed by Excise officers for proving spirit as they are not reliable for this purpose They are chiefly used in patent stills as a guide to the workman in charge

144 *Standardisation of instruments*—Hydrometers thermometers and saccharometers require periodically to be compared with standard instruments whose absolute accuracy has been determined Any errors are discovered and the necessary corrections noted on a correction card and this must be carefully consulted whenever the instrument is used The standard saccharometers hydrometers and thermometers at the Central Excise Laboratory Kasauli * have been compared with the official standard instruments in London and periodically these Indian standard instruments are also checked by other very accurate laboratory methods These are termed Imperial standard instruments Standard instruments which have periodically been compared with these standards and which are kept at whatever provincial centre is appointed by Government for the purpose may be called Provincial standard instruments At each distillery a five part glass Sikes s hydrometer standardised at the authorised centre and provided with a card of corrections should be kept as the distillery standard and used to standardise the working set of Sikes s five part glass hydrometer say, once every six months This distillery standard should on no account be used for proving spirits in the ordinary way except emergently (in case of breakage of one or more spindles of the working set) Whenever any such breakage occurs

* Now those at the Customs and Excise Central Laboratory Calcutta.

application should at once be made for replacement The distillery standard should be re standardised at the authorised centre once a year in order that errors due to any alteration in the shape of the bulb may be detected and corrected for If no alterations are recorded after two such annual standardisations, it may be assumed that the glass has settled down to its final shape, and it will be unnecessary to send it again for re standardisation unless there arises some other reason to suspect its accuracy The standardisation of the distillery working set against the distillery standard should be made by floating both instruments side by side in large glass vessels containing in turn spirit of the various strengths likely to be met with in practice The stems must be deeply plunged in the fluid and should not be released until they show a tendency to rise The card corrections required for the distillery standard should be first applied to it Then the readings of the working set should be compared with the corrected readings of the distillery standard If the reading of the working set is greater than that of the corrected distillery standard, the amount should be recorded on the card as a *minus* (—) correction If the reverse is the case, the correction will be a *plus* (+) one

A separate correction card should be prepared at each fresh standardisation of the working set and carefully used in all subsequent readings until replaced by later corrections

Standardisation of instruments used for district work should be carried out similarly by inspecting officers who should carry a standard instrument with them

145 *Care of instruments* —No Excise instrument should ever be allowed out of the custody of the officer in whose charge it is The duty of using these instruments must on no account be entrusted to menials or to any unauthorised person The responsible Excise officer alone must take all readings by hydrometer and saccharometer Saccharometers, hydrometers and thermometers after being used should be carefully washed in clean water and dried before being put away

The direction occasionally given to lift hydrometers from their box by the stem may easily lead to fracture of a spindle at the junction of stem and bulb When a spindle sticks it should be gently levered out of the case by raising the bulb

Hydrometers and saccharometers should be taken out of use if for any reason they fail to float vertically The presence of mercury in the upper bulb or hollow shaft does not make the readings inaccurate as long as the stem floats truly

Thermometers should be carefully examined from time to time to see that the mercury column has not become separated into sections and that no portion of it has lodged in the wider part at the top of the stem Should this happen the thermometer should be securely grasped by the stem towards the top

end and then sharply jerked downwards If this fails, the bulb may be gently heated until the mercury again forms one unbroken column If neither method succeeds, the instrument should be returned and another indented for in its place No thermometer which has once required such treatment should be used without careful scrutiny and if the fault occurs a second time the instrument should be taken out of use

Directions for securely packing brass and glass hydrometers for despatch are given at Appendix II

CHAPTER VIII.

Reduction and Blending.

146 *Definitions* —Reduction of spirits means their dilution with water

Blending of spirits means the mixing together of two or more spirits of different strengths

147 *The necessity for reduction* —Two leading features of the improvements in distillery processes that have taken place in recent years are the introduction of modern stills in which spirit can be produced at high strengths and the regulation of the lower strengths at which spirit is allowed to be issued from distilleries and ware houses and sold at licensed shops These involve the reduction from one strength to another of the greater part of the spirit that is distilled

148 *Reduction by rule of three* —The method hitherto used for effecting reduction has been by a rule of three calculation as follows —

Multiply the volume of strong spirit by its proof strength and divide by the required proof strength and the result will be the volume of diluted spirit *i e*, the bulk after reduction

For example —150 gallons of 40° O P spirit (140° proof) are to be reduced to 25° U P (75° proof) Find the new volume

$$150 \times \frac{140}{75} = 280 \text{ gallons}$$

149 *Shrinkage and its explanation* —The Excise control of reducing operations is somewhat complicated by the fact that when a given volume of spirit, as in the above example is reduced by adding say, 130 gallons of water, the resulting volume is not 280 gallons as might be supposed, but only about 275 gallons Thus in any series of reducing operations the total of reduced spirit is always less than the total found by adding together the strong spirit

used and the water added to it This shrinkage is due to the fact that when alcohol and water are mixed a combination of the two substances occurs accompanied by a distinct contraction or loss of volume The rise in temperature that is observed during the operation is one proof of such chemical combination The effect is greatest when 49 7 volumes of water and 54 volumes of alcohol are mixed together, only 100 volumes of spirit being obtained instead of the expected 103 7 volumes The rule for reduction which is given above correctly calculates the bulk to which any volume of strong spirit must be watered down in order to obtain a given lower strength, but, if used to calculate by subtraction the amount of water to be added, it fails to allow for the naturally occurring loss of bulk by contraction The practical results of this are that the bulk obtained is less than that calculated, but the spirit strength is correspondingly too high, and such abnormal results are undesirable in Excise control It should be understood, however, that shrinkage losses though inconvenient from the practical Excise point of view, are always losses of water, not of spirit

150 *Shrinkage exaggerated by the old Sikes's tables*—The occurrence of shrinkage would be of less consequence from the Excise point of view if the proof gallons before and after reduction were found to agree, because such agreement would supply the required Excise check So long, however, as the uncorrected Sikes's tables were employed the proof gallonage after reduction was constantly found less than that before reduction Such losses in proof gallonage, shown as wastage losses, ranged from 1 to 6 per cent of the total proof gallonage (*see* Madras Excise Manual, Second Edition, page 43, column headed "mean contraction in proof per cent") These losses were due to errors in the old tables, the proof values for certain indications (hydrometer readings) being in many cases distinctly too low, more particularly those for low strength spirits at high temperatures For example a spirit of indication 83 2 at 90° F according to the old tables is 61 9° U P or 38 1 per cent proof, whilst the reading on the corrected Sikes's tables now employed is 60 1° U P or 39 9 per cent, proof On a hundred gallons, this represents 38 1 proof gallons according to the old table, instead of 39 9 proof gallons or a difference of 1 8 proof gallons Thus, in this instance the old tables understate the proof gallonage by 1 8 in 40, that is to say they show a wastage loss of 1½ per cent which has no existence in fact

151 *Shrinkage losses removed by the reduction tables and the corrected Sikes's tables*—It is very important to realise that shrinkage losses are eliminated from the distillery stock account when the new reduction tables and the corrected Sikes's tables are employed The reduction tables show the true amount of water to be added, including that required to compensate for contraction, whilst the corrected Sikes's tables give true spirit values for all indications of the hydrometer instead of the frequently erroneous

values shown in the old tables As a result the bulk of the reduced spirit will be that calculated by the rule of three method and the proof gallons before and after reduction will agree if gauging and proving are carried out with due care and precision

The true amount of water to be added has been calculated by a method explained in Appendix IV and is shown for all reductions likely to occur in practice The corresponding bulk after reduction is given in each case to enable the Excise officer to check the unavoidable loss of water that occurs in the operation

152 *Other causes of error* —Independent of errors in working however a small apparent loss not exceeding 1 per cent of the proof gallonage will frequently appear This is referred to in the preface to the reduction tables and is due to the high temperatures prevalent in India When strong spirit is measured before reduction say at 85° F its bulk is greater owing to expansion by heat than its true bulk at the standard temperature 60 F Consequently the proof gallonage is exaggerated For a like reason the proof gallonage of the reduced spirit is also exaggerated but the error is greater in the first case than in the second and so a loss in proof gallonage appears which is in fact only the difference between two errors due to difference of temperature

Apart from this loss the proof gallonage after reduction should agree with that before reduction to within ½ per cent This ½ per cent is not due to inaccuracies in the tables but to unavoidable errors in working Any greater difference is due to errors in reading the thermometer or hydrometer or to inaccuracies in gauging the reduction vat or the vessel used for measuring out the water to be added Wooden vats moreover if used for reduction or storage are apt to cause trouble unless they have been suitably coated inside in such a manner as to prevent contact of wood and spirit A new dry vessel will absorb spirit while one which has previously been used for stronger or weaker spirit may increase or diminish the strength of the spirit placed in it The actual effect of these conditions cannot be calculated beforehand so that the state of the vessel should be considered when results other than those shown by the reduction tables are obtained A metal vessel or a wooden one lined internally so that the spirit cannot pass into the wood should be employed for reduction purposes if possible and restricted to use as a reduction vat

When discrepancies are observed in either reduction or blending operations and cannot be accounted for by carelessness or other causes indicated above the hydrometer or thermometer may be at fault or possibly the quality of the water used for reduction and the facts should be reported for orders

153 *Vats to be so arranged as to reduce mixture of spirits to a minimum* — It is further desirable that the mixture of finished spirits at different strengths

should be avoided as far as possible To this end, the result of each distillation should be passed from the receiver into a storage vat before the next distillation commences Mixture in the storage vat may, however, be unavoidable Reduction should be effected in an empty storage or issue vat or in a vat set aside for the purpose which should be emptied after each operation and used only for the mixture of spirit from the storage vats with water The spirit so mixed will be reduced to a fixed issue strength and of course there is no objection to the addition of this to spirit of the same strength in an issue vat

154 *Procedure in reduction* —To reduce a given volume of spirit of given strength to a lower strength, the reduction tables should be consulted for the amount of water to be added This should be measured out, added to the strong spirit and sufficient time allowed for the mixture to become uniform, assisted by stirring, before the reduced spirit is proved and gauged Reduction can also be correctly carried out by adding water without measuring the quantity until the bulk shown in the tables as "bulk after reduction" is obtained In this case, the mixture must be well stirred, especially towards the end and the last few gallons must be added very quietly so as to secure a level surface for reading the dip rod Care and experience are required to add the right amount of water successfully, for example, it may be desirable to reduce the bulk to some slightly higher strength as a first stage and then to complete the reduction to the required strength as a later stage By this method also there is no shrinkage because the volume is experimentally adjusted to the calculated volume As the amount of water added is not measured, it cannot be entered in the distillery records

The tables show that to obtain, for example 280 gallons of 25° U P spirit from 150 gallons of 40° O P, 135 6 gallons of water must be added The difference between the final and original bulks is only 280—150, that is 130 gallons, so that an extra 5 6 gallons of water are required This is the amount of water that disappears by contraction and is approximately the shrinkage that would be found under the old incorrect method of calculating the water by subtraction

By either of the methods now given the contraction is allowed for and so there is no shrinkage Also the proof gallons before and after reduction agree with one another, if the corrected Sikes s tables are employed, and this is the most trustworthy Excise check

155 *Excise check on bulk* —In the foregoing paragraph it has been stated that 5 6 gallons of water disappear by contraction as a result of mixing 150 gallons of 40° O P spirit and 135 6 gallons of water The proportion of water that disappears varies according to the strength of spirit reduced so that a distillery record of the water to be added is not a satisfactory Excise check on bulk because the total obtained by numerical addition is always

different from the proper total of reduced spirit The only satisfactory check on bulk is to compare the volume of reduced spirit found with that shewn in the tables as bulk after reduction and these ought to agree

156 *Procedure in blending* —It is impracticable to supply blending tables owing to the great variety of blends possible but all such operations come under one of the following cases —

Case A —To find the quantity and strength of a spirit obtained by mixing two or more spirits of different strengths

Rule —To find the quantity add up the bulk gallons

To find the resulting strength, add up the proof gallonage and multiply the total by 100 then divide by the bulk gallons The result is the percentage proof strength

Example —100 gallons at 20° U P (80 degrees proof) and 450 gallons at L P are mixed Find the resulting volume and strength

100 gallons at 20 U P	=	80 proof gallons
450 L P	=	450
550		530

$$\frac{530 \times 100}{550} = 96\ 4 \text{ per cent proof}$$

Answer 550 gallons at 3 6° U P

In this case the contraction is so small that the shrinkage it causes (one tenth gallon) is negligible Generally speaking the results calculated by the various rules now given for blending agree with those actually obtained sufficiently well for all practical purposes The shrinkage never exceeds 1 per cent of the final bulk and when it is large enough to be measured the corrected Sikes s tables show a compensating increase in the spirit strength so that the proof gallonage before and after blending remains constant and the requisite Excise check is thus afforded A method for calculating the shrinkages in each case is described in Appendix IV

Case B —A strong spirit is to be lowered to a given strength Find how many gallons of a given weak spirit must be added to do this

Rule —Multiply the volume of strong spirit by the number of degrees by which it is to be lowered and divide by the number of degrees the weak spirit will be raised by mixing

Example —75 gallons of 40° O P spirit are to be reduced to 25 O P by addition of 10° U P spirit Find the volume of weak spirit required

The strong spirit will be lowered 140—125=15 degrees and the weak spirit raised 125—90=35 degrees

$$\text{Then } \frac{75\times15}{35}=32\tfrac{1}{7} \text{ gallons}$$

Answer —$32\frac{1}{7}$ gallons of 10° U P spirit, the final volume being 75+32¹ gallons

The shrinkage here is 0 25 per cent

Case C —A weak spirit is to be raised to a given strength Find how many gallons of a given strong spirit must be added to do this

Rule —Multiply the volume of the weak spirit by the number of degrees it is to be raised and divide by the number of degrees the strong spirit will be lowered by the mixing

Example —100 gallons of 30° U P spirit are to be raised to 10° O P by addition of 35° O P spirit Find the quantity to be added The weak spirit will be raised 110—70 = 40 degrees, and the strong spirit will be lowered 135—110=25 degrees

$$\text{Then } \frac{100\times40}{25}= 160 \text{ gallons}$$

Answer —160 gallons of 35° O P spirit must be added and the final volume is 100+160=260 gallons

The shrinkage here is 0 4 per cent

Case D —A given volume of intermediate strength spirit is required Find how many gallons each of a strong and a weak spirit must be blended

Rule —Multiply the required volume by the number of degrees the weak spirit will be raised by mixing and divide by the difference in proof degrees between the weak and the strong spirit The result gives the required volume of strong spirit and the balance is the required volume of weak spirits

Example —150 gallons of 15° O P spirit are required to be made by blending 40° O P and 5° U P spirit Find the volumes of each that must be mixed The weak spirit will be raised 115—95=20 degrees and the difference between the weak and strong spirit is 140—95=45 degrees

$$\text{Therefore } \frac{150\times20}{45}=66\ 6 \text{ gallons}=\text{volume of strong spirit, and } 150—$$

66 6—83 4, volume of weak spirit

Answer —66 6 gallons of the 40° O P spirit and 83 4 gallons of the 5 0 U P spirit

The shrinkage in this example is 0 3 per cent

CHAPTER IX.

Gauging.

157 *All vessels should be gauged*—In order to ensure the correct keeping of Excise accounts it is essential that all vessels in which account for revenue is taken in a distillery, brewery or warehouse should be accurately gauged and the gauging kept thoroughly up to date The process employed differs according as the vessels are fixed or movable and, in the case of casks, according as they are empty or full, and they may be considered in that order All gauging should be done in the presence of the distiller or brewer or his agent, if he so desires, and all gauging should be checked periodically, at least once in two years

158 *Gauging of fixed vessels—the wet dipping rod*—The fixed vessels in a distillery are, or should be, the wash backs, chargers, receivers, store vats, blending vats and issue vats The gauge is taken by means of a rod of hard wood of square section divided into inches and tenths and falling perpendicularly on a brass plate let into the base of the vessel In the case of spirit vessels, to ensure that the rod cannot be slanted to one side or the other, it should be fitted at the top of the vessel with a guide at least 6 inches high and it should be shod with brass so that it cannot wear down The entry through the cover must not be large enough to allow the passage of anything beside it and the rod must be either so fixed that it cannot be removed or there must be efficient arrangements for locking the entry when the rod is not in place If it cannot be drawn fully out without touching the roof a countersunk joint may be made at a convenient point As crude pot still spirit is very destructive of iron or brass, it is advisable to use gun metal for both the hinge and the tip of the rod in distilleries at which such spirit is made

159 *Check dipping holes for large vessels*—As a check on the accuracy of the readings in large vessels every receptacle with a top diameter exceeding 60 inches should have a check dipping hole, at the opposite end of a diameter drawn from the ordinary dip hole and every receptacle with a top diameter of over 100 inches two check dipping holes, one near the centre of the vessel and the other near the side at about one fourth of the circumference of the vessel from the ordinary dip hole These holes should all be secured with revenue locks

160 *Alternatives to the dipping rod*—The distiller may also be allowed for his convenience, if he desires it, to enter a rough gauge of the contents of vessels on the outside and to provide a ready means of determining their contents by placing a float on the surface of the liquor and connecting it by

a string and pulley with an indicator working up and down the gauge so marked Another device of the same kind consists of a glass tube up the side of the vat connected with a cock at the bottom in which the spirit rises when the cock is opened to the level at which it is standing in the vat But devices of this kind should not be relied upon for revenue purposes They are not only liable to be tampered with, but frequently give incorrect readings owing to variations of the level of the float with the density of the liquor or to capillary attraction in the tube

Before commencing to gauge a vessel it is desirable to test it by keeping it full of water for 24 hours If the level of the water does not sink appreciably and there are no external signs of leakage the vessel is fit to be gauged Otherwise there is a leak to be detected and put right

161 *The drip*—The first thing to be considered in gauging a fixed vessel is what is known as the ' drip ' All vessels must be properly fixed and all connections completed before gauging is begun One of the most important of these connections is one so fixed at the bottom that the contents of the vessel can be completely emptied For this purpose it is necessary for the base of the vessel to slope slightly This must be arranged as part of its permanent setting and the insertion of wedges of wood for the purpose at the time of gauging should on no account be allowed The "drip " is, properly speaking, the quantity of liquid necessary to cover completely the bottom of the vessel, and is expressed in terms of gallons necessary to do this and of the inches and tenths at which this quantity of liquor cuts a dipping rod let down on the lowest point of the base For the sake of convenience it is more commonly reckoned as the quantity necessary for the surface of the liquor to cut the rod at any suitable division This is ascertained by measurement with a gallon pot

162 *The wet method of gauging*—The drip having been ascertained, the vessel may be gauged by either the wet or the dry method The former is generally employed in India in the case of spirit vessels which are seldom available for dry gauging and the latter for wash backs and others To gauge by the wet method in the simplest way it is sufficient to pass an un graduated rod perpendicularly downwards through the top of the vessel till it touches the base at its lowest point, then to pour in water, a fixed quantity at a time and mark off on the rod the point at which the surface of the water cuts it after each addition The quantity of liquid contained by the vessel at any such mark is the sum of the quantities poured in

163 *As applied to a frustum of a cone*—The above simple procedure, however, is cumbrous to work in practice, and the following hints will be found useful in actual working It is assumed that the vessel to be gauged is one of the commonest shape, viz, a conic frustum that is for gauging purposes a section of a cone between parallel planes

164 *Division into frusta*—Find by means of the dipping rod, or, preferably, a plumb line, dropped from the top of the vessel, the internal vertical height of the vessel at the dipping hole From this deduct the depth of the drip, and divide the remainder into frusta of 10 inches if the vertical height be 60 inches or above, of 5 inches if less than 60 Then add sufficient water exactly to fill each frustum to the nearest tenth of an inch

Thus, in the vessel for which a table is given below, the drip is shown as 1 0 inch, there are 7 frusta of 10 inches each and one at the top of 1 0 inch only The drip by measure gave 11 0 gallons, the lowest frustum contained 216 0 gallons, and so on to the top which held 17 2 or 17¼ gallons The sum of the contents of all the frusta *plus* that of the drip will give the total content of the vessel It should be noted, however, that when the top broken frustum does not, in the case of vessels of 60 inches or above, exceed 2 inches, or in the case of vessels of a less depth, 1 inch, such broken frustum should be included in the next lower complete one

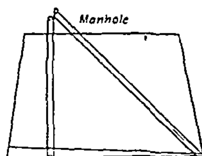
Table of dimensions

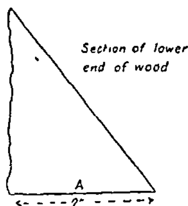
Depths	Area of an inch	Content in gallons
1 0	Cover of vessel	
1 0	17 20	17 20
10 0	17 62	176 20
10 0	18 25	182 50
10 0	18 90	189 00
10 0	19 55	195 50
10 0	20 22	202 20
10 0	20 90	209 00
10 0	21 60	216 00
1 0	Drip by measure	11 00
73 0		1398 00

NOTE—The contents were taken at 10 20 30 40 50 60 70 and 71 inches respectively from the top of the drip

165 *Filling the vessel*—A common way for an officer to satisfy himself as to the measurement of the drip is to lower a ladder through the manhole and stand on the bottom rung with a lantern while it is being measured, but care should be taken not to introduce any lights into vessels containing strong spirit vapours An alternative method is to have a piece of wood, the lower end of which is cut to an angle approximately equal to that formed by the level bottom of the vat and a line drawn to the edge of the manhole

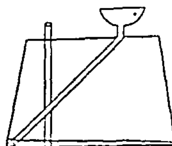
opposite to the further internal edge of the vat Thus —





When the whole of the lower surface, marked A, is found, after having been lowered into the vessel to be wetted, it may be concluded that the whole of the bottom is covered It is well to have the wood of a width not less than 2 inches so that it shall not slip into the groove where the bottom of the vat and side staves meet, technically known as the chimb

Further, to avoid delay in waiting while the liquid comes to rest after each addition, the distiller or warehousekeeper should be called upon to provide a pipe of about two inches internal diameter and of sufficient length to reach into the drip and leave a length of about 1 foot outside the manhole This portion should be bent at such an angle that when the lower end is at the bottom of the vessel and against its inner edge, it shall be vertical A large funnel is then placed in it and, inasmuch as the liquid is being continually poured beneath that already in the vat, the top surface will be found to be practically unbroken, especially after a few inches have been filled This will be found of use in saving delay in finding the drip when, the column of liquid being shallow, its surface is most easily disturbed The *space occupied by the material of the pipe is so small that it can be disregarded* The method of using is shown below —



By dividing the actual content of each frustum by its depth, the figures shown in the column headed "area of an inch" are obtained The content of each frustum as ascertained should be compared with that of those already completed as, if the vessel is of regular shape, the difference between the *content of any two adjoining frusta should be practically constant Should* any important divergence from the average be found, which, as judged by the eye, does not appear to be due to irregularity in the shape of the vessel, the water should be drawn off until the top level of the next frustum is reached and the doubtful frustum remeasured Further sub division of these by 10 will of course give the area of each tenth of an inch

166 *Tabulation of results*—Commence with the drip and continuously add to it the area of each tenth of an inch for each frustum Check the results at each inch and again at the end of each frustum by adding, in the first case, the content of an inch, in the second, the content of the frustum, to the drip for the first frustum, to the figures at the end of the previous frustum in other cases If the work has been correctly performed, the total at the end of the top inch will be that shown as the total contents in gallons

For example —

First frustum		Second frustum	
11 000—1 inch	32 600—2 inches	227 00—11 inches	247 90—12 inches
2 160	2 160	2 09	2 09
13 160	34 760	229 09	249 99
15 320	36 920	231 18	252 08
17 480	39 080	233 27	254 17
19 640	41 240	235 36	256 26
21 800	43 400	237 45	258 35
23 960	45 560	239 54	260 44
26 120	47 720	241 63	262 53
28 280	49 880	243 72	264 62
30 440	52 040	245 81	266 71
	54 200—3 inches and so on		268 80—13 inches and so on

If this addition is continued for each successive frustum the total at the 72nd inch will be that shown in the last column of the table of dimensions

167 *Preparation of a table*—These figures are then transferred to the table below, all figures in decimals except the first being disregarded—

Inches	Tenths 0	1	2	3	4	5	6	7	8	9
Drip										
1	11 0	13 1	15 3	17 4	19 6	21 8	23 9	26 1	28 2	30 4
2	32 6	34 7	36 9	39 0	41 2	43 4	45 5	47 7	49 8	52 0
3	54 2									
11	227 0	229 0	231 1	233 2	235 3	237 4	239 5	241 6	243 7	245 8
12	247 9	249 9	252 0	254 1	256 2	258 3	260 4	262 5	264 6	266 7
13	268 8									
70	1363 7	1365 5	1367 3	1369 0	1370 8	1372 5	1374 3	1376 1	1377 8	1379 6
71	1381 4	1383 1	1384 8	1386 5	1388 2	1390 0	1391 7	1393 4	1395 1	1396 8
72	1398 6									

In preparing the table do not divide the drip

When the contents of the top frustum cannot be exactly divided by the depth the area should be calculated to three figures of decimals Any adjustment that may be necessary should be made at the end of the tabulation so that the full capacity in the tables shall correspond with the total contents in the dimensions tables

All calculations should be taken to the nearest quarter gallon, a quarter being entered as 2 a half as 5 and three quarters as 7

In tabulating results the content of each tenth of an inch should be taken to three figures in decimals For the table, however, one figure in decimals in the case of spirit vessels is sufficient in the case of wort or wash vessels the integers alone should be used

168 *An alternative method*—An alternative method is to fill the vessel up in the first instance then open the discharge cock and measure the quantity of water which passes out of each segment of 5 or 10 inches as the case may be shutting the discharge cock immediately the dip in wet inches shows that the bottom of a segment has been reached, and to continue in this way until the dip shows that the surface of the drip has been reached The method of tabulation is similar except for the fact that the broken frustum will come immediately above the drip

169 *The dry method*—The dry method is adopted in the case of all fixed vessels in breweries and generally in that of all but spirit vessels in distilleries

and is based on actual interior measurements of vessels calculation of their cubical contents in inches and computation of their liquid contents in gallons by reference to the fact that the standard for the imperial gallon is the space occupied by 10 lbs avoirdupois of distilled water at a temperature of 62° F, or more briefly, 277 274 cubic inches

170 *Finding the area of the base* —The first process in such a mathematical computation is to find the area of the base of the vessel The vessels commonly met with are either cubical cylindrical in the shape of conic frusta or elliptical vats with sides sloping inwards from the base upwards

For a calculation of the base of any of these careful measurement with a steel tape and the application of one of the following rules will suffice —

(*a*) the area of a rectangle is found by multiplying its length by its breadth

(*b*) the area of a circle is found by squaring the diameter and multiplying by 7854

(*c*) the area of an ellipse is found by multiplying its major and minor axes together and then multiplying by 7854

It should be noticed however, that the slighest error in the calculation of the area of the base will vitiate all the subsequent calculations Moreover repeated measurements enable the operator to detect irregularities in apparently regular vessels This being so, it is customary never to rely on the result of one measurement Thus in measuring a rectangular area the length and breadth should be measured in five or six different places, with a circular base five or six diameters should be taken

An elliptical vessel requires somewhat more care The major axis of an ellipse may for gauging purposes be defined as the longest straight line that can be drawn within the confines of the ellipse The minor axis is the shortest line that can be drawn through the centre of the major axis To find the lengths of these axes in practice proceed as follows —By a process of trial find by means of a steel tape or piece of well made fine cord, the greatest diameter or major axis of the bottom of the vessel Measure this and draw it in chalk along the floor of the vessel This is conveniently done by chalking a piece of cord, holding it taut and then 'striking' it by lifting it up in the middle and letting it go again Then find the length of the shortest diameter or minor axis If the vessel is well made these two lines will cut one another at right angles and will also bisect each other and these properties may be used as a check As a further test whether these two lines really represent the major and minor axes the following plan may be resorted to Having found a trial line for, say, the major axis draw lines parallel to this and distant one, two, three, etc, inches from it on both sides The lengths of each pair of lines on opposite sides should then be equal A similar process of check can be applied to the minor axis

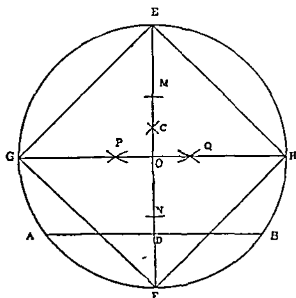
171 *Construction of a table for a regular vessel* —The area of the base having thus been ascertained and the drip recorded, the next step is to construct a table showing the liquid contents of the vessel for each inch of depth above the drip In a regular vessel this is a simple matter The contents in cubic inches are found by multiplying the area of the base as found in square inches by the depth required, 277 274 cubic inches are equal to one imperial gallon; so that the division of the result by that figure and the addition of the drip gives the contents of the vessel in gallons at any desired point This calculation can be checked by the wet method at convenient intervals A table showing the areas of circles of different diameters is printed as Appendix V.

172 *Irregular vessels—conic frusta* —If a vessel is irregular in more than one respect it is not possible to construct a table mathematically and the wet method must be resorted to, but, in the case of the most common of the irregular vessels, those in the shape of a frustum of a cone, calculation can be and is resorted to The rule to be observed in finding the cubic contents of a frustum of a cone is —

Add the areas of the two ends and the mean proportional between them together and the sum multiplied by one third the perpendicular height, is the cubic content The mean proportional is found by multiplying the areas of the two ends together, and taking the square root of the product

173 *Laying out the base* —The following however is the method more commonly followed in practice —

Let the diagram represent the bottom of the vessel to be gauged and tabulated With a chalked cord strike a line in any part of the bottom as A B, and from centres A and B describe arcs cutting each other in C, through the point C and through the middle of the line AB at point D, strike the line EF, the middle of which, O, will be the centre From O mark off two equal distances, OM, ON; with centres M and N describe arcs cutting each other in P and Q; through these points strike the line GH, the bottom will



be truly quartered in the points E, H, F, G, between these points strike the lines EH, HF, FG and GE, it will be found convenient if the points A and B are so selected that either EF or GH passes through the dipping place From the top of the vessel let fall perpendiculars on the diameters struck, and from the extremities of the diameters to the points whence the perpendiculars were let fall strike up the sides of the vessel the lines on or between which, cross diameters are to be taken If the work has been correctly performed, the square at the top of the vessel will correspond in position with that at the bottom, but it will of course be smaller if the vessel tapers The mean of the cross diameters multiplied by 707 should give the side of the inscribed square, i e, the length between the ends of the diameters

174 *Division into frusta*—From the top of the vessel measure off one-half the depth of one of the frusta into which the vessel is to be divided From this point full frusta should be measured As the depth of each frustum is measured vertically, the equivalent length along the side of the vessel must be calculated The total vertical height is 72 inches Find the total slant height of the inside of the vessel It will be 72 2 Then each 10 inches of vertical height corresponds to 10 003, a difference which is quite negligible Many vessels, however, slope more, and the difference frequently amounts to more than one tenth of an inch Mark the points on the chalked lines on the sides and have them distinctly cut in the wood with a graving tool either by a cross or a circle, the centre of which is the point of intersection Thus, in a vessel which is to be divided into 10-inch frusta the first measurement will be taken at 5 inches from the top of the vessel the others at 15, 25, and so on The lowest frustum will rarely be a full one in this case see how much is left between the bottom of the last frustum and the top of the drip and divide it by 2

An example will make this plainer In the vessel shown in the table below there are 7 full frusta of 10 inches each their dimensions being taken, as shown in the note appended thereto in the middle of each Between the bottom of the lower frustum and the top of the drip, however, there is a space of 1 inch which is regarded as a separate frustum Now the bottom of the lower frustum extends to 70 inches the middle point of the frustum of 1 inch will therefore be at 70 5 inches from the top of the vessel In practice, however, it would be sufficient to group together the two lowest frusta and regard them as one of 11 inch depth, in this case the dimension for the single frustum would be the mean between 60 inches (the bottom of the frustum next higher) and 71 inches the top of the drip, it would therefore be taken at 65 5 from the top of the vessel Such broken frusta, if, in the case of 10-inch frusta, not exceeding 2 inches, and, in the case of 5-inch frusta, not exceeding 1 inch, should always be grouped with the next higher ones

Depths	Diameters 1	2	Mean	Area of an inch	Contents in gallons
10 0	78 7	78 7	78 7	17 54	175 40
10 0	80 1	80 0	80 0	18 13	181 30
10 0	81 4	81 2	81 3	18 72	187 20
10 0	82 6	82 7	82 6	19 32	193 20
10 0	83 9	84 0	83 9	19 93	199 30
10 0	85 3	85 1	85 2	20 56	205 60
10 0	86 5	86 6	86 5	21 19	211 90
1 0	88 0	87 9	87 9	21 88	21 88
1 0	Drip by measure				11 00
72 0					1,386 78

NOTE—The dimensions were taken at 5 15, 25 35, 45 55, 65 and 70 5 inches, respectively, from the top of the vessel

175 *Calculation of mean diameters*—This method of measuring frusta of a cone depends upon the fact that, for all practical purposes, any frustum may be regarded as of equal content with a cylinder of the same height with a diameter equal to the middle diameter of the frustum Thus a frustum 10 inches in depth with an upper diameter of 70 inches and a bottom one of 72 would be regarded as being of equal capacity with a cylinder having a diameter of $\frac{72+70}{2}=71$ inches

By calculating this example by both the accurate and approximate methods it will be shown that, in practice, the method of mean diameters is quite justifiable —

Accurate method—

(*See* para 172)

Squar inches

$$70^2 \times 7854 = 3848\ 46$$
$$72^2 \times \cdot 7854 = 4071\ 51$$
$$\sqrt{(3848\ 46 \times 4071\ 51)} = 3958\ 42$$
$$3)\ 11878\ 39$$

True area in sq in 3959 46

Approximate method—

$$\left(\frac{70+72}{2}\right)^2 \times 7854 = 3959\ 20$$

Difference on 1-inch frustum= 26

The difference on a 10-inch frustum is thus only 2 6 cubic inches = 009 gallon

It must be borne in mind, however, that this approximation would not have been so close if such a pair of numbers as 67 and 75 (with mean 71 as before) had been chosen; with these latter numbers the difference on a

10-inch frustum would have been 41 9 cub in = $\frac{1}{6}$ gallon nearly. It follows from this that the greater the number of frusta into which an irregular vessel is divided the more accurate will the tabulation be In illustration of the way in which even so small an error as $\frac{1}{100}$ th of a gallon in the complete frustum can affect the tabulation the following table is added Top diameter 70 inches, bottom diameter 72 as above

Ordinary tabulation with 10 inch frusta		True gauges	Error
	Cubic inches	Cubic inches	Cubic inches
Full	39 592	39 595	3
1	35 633	35 741	108
2	31 674	31 858	184
3	27 714	27 954	240
4	23 755	24 031	276
5	19 796	20 080	284
6	15 837	16 108	271
7	11 878	12 115	237
8	7 918	8 100	182
9	3 959	4 061	102
10	*nil*	*nil*	*nil*

There is thus a difference at 5 inches of almost exactly one gallon, which is the limit of accuracy of the method in this particular case Generally speaking, a vessel with sloping sides should be divided into such a number of frusta as will secure that the difference between the successive mean diameters shall not much exceed one inch

To apply the method in practice having laid out the sides of the vessel, take with a tape the dimensions of each diameter from the marked points and post them in the above table The total vertical depth of the vessel should be shown in column 1 and the aggregate of the several frusta and of the drip must correspond with this

Where the vessel is of irregular section it may be necessary to take four cross diameters to obtain a practical mean, this is done by bisecting a line drawn from the ends of the two cross diameters (such line being a side of the inscribed square), and drawing a line through the point of bisection and the centre of the circle This being done on two adjacent sides of the square, two other diameters are obtained at equal distances from the original ones

The mean diameter is obviously found by adding together the separates and dividing by the number taken Thus in the second frustum of the table —

$\frac{80\ 1+80\ 0}{2}$ = 80 05, which is reckoned as 80 0, and in the fifth $\frac{83\ 9+84\ 0}{2}$ = 83 95, reckoned as 83 9

The rule is to disregard in the final result all decimals but the first.

176 *Calculation of contents* —Having obtained the mean diameter, find the capacity (known technically as the area) for each inch of depth

Rule—Square the diameter, multiply by 7854 and divide the product by 277 274, the cubic inches in a gallon, thus —

$$\frac{78\ 7\times 78\ 7\times\ 7854}{277\ 274}=\frac{6193\ 69\times\ 7854}{277\ 274}=\frac{4864\ 524126}{277\ 274}=17\ 54$$

The area of each inch must be multiplied by the depth of each frustum, the total being carried to the last column To these totals add the drip as found by actual measurement, the grand total will be the total content of the vessel

177 *Method of tabulation*—The method of tabulation is simple from the total content continuously subtract the gallons in each inch of each frustum If this is correctly performed, the final remainder will be the drip Thus —

Top frustum	Second frustum	Third frustum	Fourth frustum	Fifth frustum	Sixth frustum	Seventh frustum	Eighth frustum
1386 78	1211 38	1030 08	842 88	649 68	450 38	244 78	32 88
17 54	18 13	18 72	19 32	19 93	20 56	21 19	21 88
1369 24	1193 25	1011 36	823 56	629 75	429 82	223 59	Drip 11 00
1351 70	1175 12	992 64	804 24	609 82	409 26	202 46	
1334 16	1156 99	973 92	784 92	589 89	388 70	181 21	
1316 62	1138 86	955 20	765 60	569 96	368 14	160 02	
1299 08	1120 73	936 48	746 28	550 03	347 58	138 83	
1281 54	1102 60	917 76	726 96	530 10	327 02	117 64	
1264 00	1084 47	899 04	707 64	510 17	306 46	96 45	
1246 46	1066 34	880 32	688 32	490 24	285 90	75 26	
1228 92	1048 21	861 60	669 00	470 31	265 34	54 07	
1211 38	1030 08	842 88	649 68	450 38	244 78	32 88	

178 *Preparation of a table*—Prepare a table in the form below, and in the column marked "gallons" put the figures found against each inch (disregarding all decimals) in the tabulations In the third column place the area of each tenth of an inch for each frustum The method of calculating contents for any dip is given in the note attached to the table

As the vessels to which this method applies are generally filled to the same height on each occasion, the table need not be carried down to the bottom unless such a course is preferred In practice, it is generally calculated down to about 5 inches below the depth to which the vessel is generally filled and the vacuity is gauged instead of the liquid content Should, however, it be filled to a depth not calculated, the content at that depth can easily and readily be found by referring to the tabulation, which should be retained in the office

Inches	Gallons		Area of a tenth	Inches	Gallons		Area of a tenth
1	2	3	4	5	6	7	8
Full	1 386			40	649		
1	1,369	2		41	629	2	
2	1 351	4		42	609	4	
3	1 334	6		43	589	6	
4	1 316	8		44	569	8	
5	1 299	9	1 754	45	550	10	1 993
6	1 281	11		46	530	12	
7	1 264	13		47	510	14	
8	1 246	15		48	490	16	
9	1 228	16		49	470	18	
10	1 211						
11	1 193	2		50	450		
12	1,175	4		51	429	3	
13	1 156	6		52	409	5	
14	1 138	8		53	388	7	
15	1 120	10	1 813	54	368	9	
16	1 102	11		55	347	11	2 050
17	1 084	13		56	327	13	
18	1 066	15		57	306	15	
19	1 048	17		58	285	17	
20	1 030			59	265	19	
21	1 011	3					
22	992	4		60	244		
23	973	6		61	223	3	
24	955	8		62	202	5	
25	936	10	1 872	63	181	7	
26	917	12		64	160	9	
27	899	14		65	138	11	2 119
28	880	15		66	117	13	
29	861	17		67	96	15	
30	842			68	75	17	
31	823	2		69	54	20	
32	804	4					
33	784	6		70	32		
34	765	8		71	Drip 11 21	.	2 188
35	746	10	1 932	72	Empty		
36	726	12					
37	707	14					
38	688	16					
39	669	18					

Note.—The figures in columns 3 and 7 show the number of gallons to be deducted for each ... any ... be ... ling

179 *Dry dipping rod and float rod* —In cases in which vacuity is to be gauged as above and not liquid content, a different instrument to the wet dipping rod is used This is either a dry dipping rod or a float rod The graduations of a dry dipping rod commence from a brass bracket which projects at right angles from near the top of the rod The underside of the brass bracket is to be brought into contact with the dipping plate of the vessel to be dipped. This dipping plate is of brass and usually let into the top end of one of the side staves of the vessel

In cases where vigorously fermenting, frothy liquids are dry dipped a rectangular block of cork is attached to the end of a short wet dip rod On gently pressing the cork down on to the true liquid surface, the number of dry inches from the dipping plate can be estimated to within, say, half an inch, due allowance for the thickness of the cork having been made by the maker of the rod Such a dipping rod is called a " float rod "

180 *Allowance for incumbrances* —In preparing the tables full allowances should be made for internal incumbrances such as brackets, stays, attemperating coils, yeast discharge pipes, etc

181 *Regauging* —Regauging of vessels originally gauged by this method simply requires verification of the diameters from the points already marked Should many of them differ more than 3 per cent or any of them differ by more than 5 per cent a fresh gauging is necessary and new tables need to be constructed accordingly It must be remembered that circular vessels vary in area directly as the square of their diameters , a variation of 3 of an inch in the diameter of a vessel of 80 inches would therefore only represent a difference of 13 gallon in the capacity at the depth of one inch An example is given for reference

Inches		Gallons	Difference in gallons per inch of depth
Diameter	79 7 =	$\frac{79\ 7^2 \times\ 7854}{277\ 274}$ = 17 99	13
"	80 0 =	$\frac{80\ 0^2 \times\ 7854}{277\ 274}$ = 18 12	
"	80 3 =	$\frac{80\ 3^2 \times\ 7854}{277\ 274}$ = 18 26	14

Obviously if all the diameters showed either an increase or a decrease to the extent of the factors given it would be necessary to recast the contents throughout

182 *History of vessels* —As stated above regauging of all vessels should be performed every two years and one half should be done each year. To

ensure this being done it is well for an index table to be placed in front of the table book embracing the whole history of the vessel

183 *The gauging of casks for storage of liquor* —When casks are used for storage of liquor they should be treated as fixed vessels and gauged by the wet method as explained in paragraphs 162—168 above Casks of good standard shape should be selected, *viz*, those that most nearly approach the spheroidal In the case of liquor casks of a capacity of 50 gallons or thereabouts the quantity measured into the cask will be found to agree very closely with the quantities found from calculation by the bung rod and the ullage slide rule and it will be sufficient to record the number of the cask, its capacity by actual measurement and the difference between this and the quantity shown by bung rod calculations at one fourth, one half and three fourths of the capacity of the cask respectively The cask can then be gauged in the manner shown below and the necessary correction applied

184 *Casks used for issue and transit* —In dealing with casks used in the issue and transit of liquor there are three stages to be considered In the first place the true contents of the empty cask should be accurately ascertained, in the second place an accurate account should be kept of liquor issued into it on payment of duty in the third place provision must be made for check of the contents in transit or on arrival

185 *Record of full content* —Every cask should be accurately gauged, preferably by the wet method and the contents marked on the head when it is first brought into use and these measurements and entries should be corrected whenever it is returned to the issue room after a journey or after coopering A register should be maintained at each distillery of all casks in use

186 *Measurement of quantity issued* —Issues are commonly measured into casks by gallon pots A device which is useful in preventing spillage in this process as well as in gauging by the wet method consists in a vessel holding exactly one or two gallons which can be connected by pipes both with the discharge pipe of the issue vat and the bung of a cask and closed after each discharge of its content so that any desired number of gallons can be poured into a cask by repeatedly filling it from the vat and emptying it through the bung

187 *Weighment an alternative* —Another method of reckoning quantities issued is by weighment For this purpose the following procedure may be observed —

(i) Before any spirits are put into a drum or cask for removal, the officer must ascertain the weight of the drum or cask with its screw plug or bung and enter it along with the mark and number in a register

(ii) The weights of several drums or casks may be ascertained before any are filled, but should such drums or casks not be filled

before the close of the following day the weights must be checked before filling It must of course be seen that the casks are reasonably dry at the time of weighment, otherwise great variations might result

(iii) Whenever any spirits are put into a drum or cask it must be filled up at once, and the gross weight and the hydrometer indication of the spirits immediately ascertained and entered in the weighing book so that the contents of the cask may be calculated Care must be taken that the temperature of the spirits in the sample alters as little as possible before the indication is ascertained

(iv) Drums or casks, whether empty or full, should be weighed to a pound, but in the former case the weights should be allowed to preponderate and in the latter the drum or cask

(v) *The number of gallons contained in the drum or cask is ascertained* as follows —

Refer to the specific gravity table (No 1) at the end of the Sikes's tables and against the hydrometer indication already ascertained will be found the "specific gravity" or, more correctly, the weight in pounds per gallon of the spirits tested Then divide the net weight of the spirits (that is the difference between the weights of the full and empty casks) by the specific gravity and the quotient to the first decimal place will be the contents of the drum or cask in gallons

These calculations may be saved by the use of Livingston's and Loftus's tables* of the weights of spirits, in which they are fully worked out

188 *Check of contents on arrival*—For check of the contents of casks in transit or on arrival or in any case in which it is not possible to measure or weigh them, in other words in cases in which the content of full vessels is required, gauging by bung rod or callipers and computation of their contents must be resorted to For the purpose of using these instruments, although casks vary considerably in build, they are all assumed to be of a standard shape, *viz*, what is technically called the middle frustum of a prolate spheroid, *i e*, the middle section of the solid described by the revolution of an ellipse about its major axis Additions to or deductions from the length are made when necessary to reduce each cask to the standard figure

189 *The parts of a cask defined*—The curved portion of a cask is composed of curved pieces of hard wood, which are known as staves, held together by wooden or iron hoops which bind them tightly to the circular discs called heads which form the two ends of the cask

*In some provinces Gibbs's tables of the weights of spirits in which the capacities of casks from 40 to 80 gallons roughly, are fully worked out are used.



The heads are composed of straight planks often somewhat thicker than the staves The staves project somewhat beyond either head, and the circle of junction between the staves and the head is known as the chimb The curved portion of the cask (composed of staves) between the bung and the head is known as the quarter If the slope from bung to head is uniform and considerable the cask is described as having a lean quarter Casks with full quarters slope very little from the bung until near the head, when they abruptly slope away to enclose a head which often is rather small than otherwise The total holding capacity of a cask is called its content, the number of gallons of liquid in a partially filled cask is called its ullage, and the unfilled portion is described as its vacuity It should be noted that, etymologically, the word ' ullage means the unfilled portion of a cask, *i e*, exactly the converse of its modern meaning in gauging

190 *Instruments used—the bung rod*—The bung rod is a dipping rod specially made for casks It is usually 48 inches long of square section shod with brass at both ends and provided with a brass slide The point of the rod is bevelled off so that it may more readily reach into the angle of the chimb of the cask From the lower part of the slide a flange projects to a length of one inch so that when the dipping rod is in position in the cask this flange may be slid down until too large to pass through the bung hole it is stopped by the bung stave By means of notches cut on the springs attached to the lower part of the slide at $\frac{3}{4}$ and $\frac{1}{2}$ inch from the flange allowances for the thickness of bung staves may be made without mental subtraction Two opposite sides of this rod are graduated in inches and tenths On a third side is marked the Imperial area line, while the diagonal line appears on the fourth side

191 *The Imperial area line*—The Imperial area line, which appears in the diagram is constructed on the principle that the areas of similar figures vary as the squares of their like dimensions Since a circular vessel of diameter 18 79 inches has an area of 277 274 square inches and filled to the depth of one inch, would hold exactly one gallon, the content of any other circular vessel at one inch of depth may be found by the undermentioned formula —

$(18\ 79)^2$ (any given diameter)^2 1 gallon required content in gallons

This line on the bung rod shows against each diameter the equivalent gallons per inch, which multiplied by the perpendicular depth, will give the required content in gallons

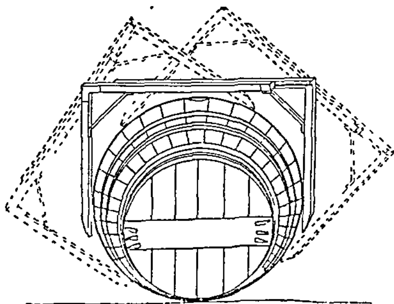
192. *The diagonal line*—The diagonal line is constructed on the principle that similar solids vary as the cubes of their like dimensions For example, assuming that a cask with a diagonal of 16 4 inches has a content of 10 gallons, a cask with a diagonal of 32 8 inches would have a content of 80 gallons

The diagonal line on the bung rod is useful for checking the content of quarter casks and smaller sizes and also as an approximate check in gauging larger casks, but it should not be relied upon as it will give fairly correct results only when the cask is of suitable length and shape Should a cask be short, or have a perpendicular bung in excess of the cross, the diagonal may show a content as much as two or three gallons greater than the actual content On the other hand, should the cask be flattened, or the cross be greater than the perpendicular bung diameter, the result found by the line will be less than the true content

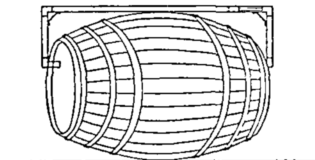
The rod should be inserted into the cask so as to allow the bevelled end to enter the angle formed by the head and long staves The reading should be taken at the level of the under side of the bung stave, and in the centre of the bung hole In all cases the diagonal should be measured from each head, and the mean taken

193 *The head rod*—The head rod is used for several purposes First, as its name implies, it is used for measuring the heads of casks, secondly, as a slide rule, it is used both for casting contents and for working ullages These operations will be described in detail later

194 *The cross callipers*—The cross callipers are used for finding the outside horizontal bung diameter of casks The graduation of these instruments and their method of use will be best understood from an inspection of the instruments themselves



195 *The long callipers*—The long callipers are used for measuring the length of casks, that is, the straight line distance outside from head to head They are turned inwards at their ends so as to reach the heads of the casks without touching the projecting ends of the staves The thickness of the heads of casks being fairly uniform, the graduations of the instrument indicate two inches less than the actual measurements



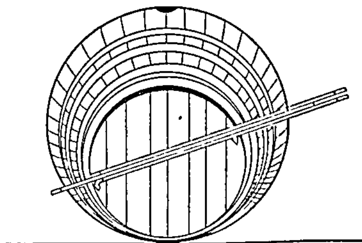
196 *Method of use of these instruments*—An example of gauging a partly filled cask follows —

With the cross callipers the external diameter of the cask is measured first, horizontally and then at as great an inclination on each side as can conveniently be made The mean of these three measurements is reduced by twice the estimated thickness of the staves The estimate requires considerable practical experience, assume for example that the staves are reckoned as 1 inch thick and the mean external diameter has been found to be 33 2 inches Deducting 2 inches an estimated internal diameter of 31 2 inches is obtained Mark this in chalk to the right of the bung hole of the cask Taking the bung rod, move the brass slide up to the top out of the way, then pass the rod through the bung hole until the bottom of the cask is reached, care being taken to pass it perpendicularly Next press down the brass slide until its flange rests fairly on the bung stave On withdrawing the rod, the reading should be made from the extreme end of the brass springs in order to allow 1 inch for thickness Suppose the

diameter thus indicated is 31 4 On comparing this "perpendicular bung" with the cross or "horizontal bung" previously taken it will be found to be 2/10ths more Take the mean figure 31 3 as representing a fair estimate The length is now taken with the long callipers Suppose they show 49 6, 49 8, 49 7, the average is 49 7, this is accepted as final as the long callipers are made to show 2 inches less than the actual measurement The head diameter is next required Both front and back heads are taken Suppose the mean figures 22 8 and 22 6 are obtained, respectively. Then 22 7 may be taken as the head diameter Sufficient measurements are now available for casting the content The measurements are—

Length	49 7 inches
Head	22 7 ,,
Bung	31 3 ,,

The head rod is now used and the brass projection of the slide known as the "cock" is adjusted to the mean head diameter 22 7 Look along the lower line of the rule for the bung diameter, exactly over this on the middle or spheroidal line of the slide will be found 6, look for this number on the line of inches on the side below it, and immediately under, on the inch line of the rule, will be found the mean cylindrical bung 28 7 inches, which



is the diameter of a cylinder that at the same length as the cask would contain the same quantity of liquor Now set the gauge point, which is

marked very conspicuously in black on the upper line of the slide, to the length 49 7 on the upper line of the rule, and look along the upper line of the slide for the mean cylindrical bung, above which, on the rule, will be found the capacity of the cask, which in the present instance will be 116 gallons But the cask is not full Take the bung rod and, lifting the brass slide up out of the way, carefully dip the cask, taking care to keep the rod vertical Note where the liquor has marked the rule, say, at 25 8 inches Turn to the back of the head rod and bring the bung diameter 31 3 on the lower line of the slide over 100 on the segment line, noting what division on the segment line is under the wet inches on the lower line of the slide This found, place the slide so that 90 0 on it shall be over 100 on the segment line and then look for the content of the cask on the upper line of the rule, under which, on the slide will be the gallons in the cask, *viz*, the ullage, which in this case is 104 7

197 *Allowances for variations*—The chief difficulty in the above series of operations is of course the making of an accurate estimate of the thickness of the staves This can only be satisfactorily acquired by practice In the first place, the wood used by coopers is not sawn, but rent or hewn into shape in order that the fibre may retain its utmost strength The thickness, is, therefore, never uniform Again the outlines of the staves, and hence the figure of the cask, are produced under the guidance of the eye alone, and although coopers by long practice become extraordinarily expert it is evident that the line of curvature so formed cannot possibly be mathematically correct, or even in its own form invariable It therefore not unfrequently happens that a cask may have a full figure on one side, and a spare and bad one on the other, so that it would be likely to be either under or over gauged, according to the portion that may be uppermost This inequality of figure is rarely perceptible unless the cask be placed upright on its head and viewed from all sides Again a cask whose outward figure may be very good, may, from inequality of thickness within, be nearly the reverse, as in making the casks the staves are often thinned at the bouge to facilitate their curvature, and at the chimb to equalize them and improve the outward appearance, while the internal thickness and inequalities are left untouched Elsewhere on the contrary, some casks are purposely thinned at the quarter, and at the bung and chimb are left to their full thickness In view of the above facts, gauging allowances, that is, additions to, or deductions from, the mean dimensions actually found by measurement, are sometimes made for particular casks or classes of casks, but none but an experienced gauger can hope to apply corrections of this sort with success, and it should therefore never be attempted except by those who are constantly dealing with casks of various shapes and who have repeatedly checked their results against actual trial with water.

198 *Use of instruments by Excise officers*—The duties of distillery officers are generally speaking much simpler, inasmuch as the full content of the

casks they have to deal with has almost invariably been accurately gauged The following instructions are generally sufficient for their purposes —

(1) See that the cask is perfectly level and that the bung hole is exactly in the centre at the top

(2) Pass the bung rod with the triangular point downward through the centre of the bung hole until it touches the bottom of the cask Bring it to the side of the bung hole and read the figures marked on the side of the rod visible above the surface of the cask Then find the thickness of the top stave (in casks of 50 to 60 gallons capacity, this is generally about $\frac{3}{4}$ of an inch, or, as the rod is marked in inches and tenths of an inch seven tenths), deduct the thickness from the outside depth or diameter, the difference will be the true internal diameter of the cask, known as the bung diameter

(3) Carefully wipe the rod and again insert it through the bung hole, taking care to keep it upright Lower it slowly and steadily through the liquor so as not to break the surface, and directly it touches the bottom press it downwards slightly and immediately withdraw it Note the point to which it is wet, taking the wet tenth when the line falls between two divisions

199 *The ullage table for lying casks*—(4) Divide the number of wet inches and tenths by the bung diameter previously found, refer the quotient to the table printed as Appendix VI, directly opposite which will be found its equivalent Multiply the equivalent by the content of the cask as marked upon the head, the product will be the actual quantity of liquor in the cask

Examples—

(1)

Bung	wet inches	quotient		Equivalent
26 5)	22 8	(860	=	931
	2120		content	55 gallons
	1600			4670
	1590			4670
				51 370 gallons

Answer—$51\frac{3}{10}$ gallons ullage quantity

FIG

I

A

B

C

SEG. LY.

II

III

IV

(2)

Bung	wet inches	quotient		Equivalent
29	) 15 5	(534	=	5476
	145		content	52 gallons
	100			10952
	87			27380
	130			28 4752 gallons
	116			

Answer—$28\frac{4}{10}$ gallons ullage quantity

(3)

Bung	wet inches	quotient		Equivalent
21 6	2 7	(125	=	054
	216		content	32 gallons
	540			108
	432			162
	1080			1 728
	1080			

Answer—$1\frac{7}{10}$ gallons ullage quantity

200 *The ullage slide rule*—The necessity for these calculations can be avoided by the use of another instrument called the ullage slide rule, the nature and use of which will best be understood from the diagram opposite and the examples below —

The lines marked A and B, respectively, are graduated alike and in logarithmic proportion so that, by setting one multiplier on B to 10 A and then looking along A for the other multiplier, the product of the two numbers will be found immediately below the latter on line B The rule is sub-divided decimally, consequently it must be borne in mind that the vacuity in a cask may be represented by the same figures on the slide rule whether it be tens of gallons, gallons, or tenths of a gallon, but there can be no confusion on this head as the depth of liquid in the cask will indicate sufficiently which of the three it must be The sub-divisions on the rule must be regarded as tenths or two-tenths according to the number between each whole number

Figure 1 gives an example of multiplication —

Multiply 64 by 54, or 6 4 by 5 4, or 64 by 54, as the case may be

Look along line B for 64, set 64 to 10A Look along line A for 54 and immediately below 54 will be seen 345 on B There must be four figures in the product, the last of which must obviously be 6 Hence the product is 345 6, 34 56 or 3 456

Take another example of multiplication —

Multiply 40 8 by 50 8, 4 08 by 5 08 or 408 by 508

40 5 and 41 0 are clearly marked on the rule and 40 75 is of course midway between the two, but 40 8 is not marked

The slide must be so adjusted that what may be considered as 40 8 is set to 10A

Look along line A for 50 8 and immediately below on line B will be found 20 6 or 2 06, or 206 as the case may be

The rule is not divided finely enough to enable the reader to be sure whether the third figure should be 6 or 7, but it is near enough for practical purposes, as will be seen below

The line marked "Seg Ly" is sub divided to show the percentage of its capacity contained in a spheroidal cask according to the depth of the liquid remaining in it when dipped at the bung hole with the cask lying horizontally This line is based on the average results of a series of experiments on a number of casks

Figure 2 illustrates the method of finding the contents of a cask of 54 gallons capacity —bung diameter 26 5 inches,—wet inches 17 5

Set 26 5 (bung diameter) on line C to 100 on segment line (100 Seg Ly)

The difference between 26 5 and 17 5 is 9 0 *Look along line C for 9 0* and on the segment line immediately below will be found 28 0 This is the percentage of the capacity which is empty Set 28 0 on line B to 10A and under 54 (the capacity of the cask) on *line A will be found* 15 1 on line B (by multiplication by the pen this is actually 15 12)

Whenever the capacity line on A falls between two sub-divisions on line B the first place of decimals must be increased by 1, as illustrated above This is the only safe rule to lay down, because the second and third places of decimals are not easily read and only represent very small fractions of a gallon

Deduct 15 2 from 54 and the contents of the cask are 38 8 gallons This is generally called the "ullage" gallons

Again A cask 53 5 gallons capacity, bung diameter 26 2 and wet dip 21 6, vacuity 4 6 inches

Percentage on Seg Ly 9 75

Vacuity in gallons=5 22 approximately, called 5 3

Ullage gallons or contents=48 2

When the vacuity is less than 1 inch set the bung diameter on line C to 10 on the segment line Look along C to the right of 10 on the segment line for the number of tenths, and under the number of tenths of an inch will be found on the segment line the percentage Work out the vacuity as before

Figure 3 gives an example —

Capacity of cask 53 0 bung diameter 26 3 wet inches 25 5 vacuity 8

$\frac{8}{10}$ on C cuts the segment line at 56 very nearly, and equals 56 in this case Multiply out 56 per cent as already described and the product is 29 of a gallon

Thus vacuity in gallons 29 = $\frac{3}{10}$ ths of a gallon and therefore the contents are 52 7 gallons

When the cask is less than half full the working must be on the wet inches

Example —Capacity 54 5 bung diameter 27 2 wet inches 12 5 12 5 cuts the segment line at about 44 2

Note that in this case each of the sub divisions between 12 and 13 on the line C is equal to 2/10ths

Contents 24 0 gallons

In these cases, whenever the capacity line falls less than midway between two sub divisions the excess fraction of less than a quarter of a gallon may be ignored

In the latter case if the capacity had been 55, the ullage gallons, *i e*, the contents, would have been 24 2

Figure 4

Capacity 108 bung diameter 33 8 wet inches 24 6 vacuity 9-2 inches

Percentage on segment line 19 99 very nearly

The capacity will be found between "1" and "11" (or 100 and 110) on the left hand The sub-divisions must be reckoned as 2 gallons each.

Therefore the vacuity equals 21 5 gallons and the contents 86 5 gallons.

[N B —20 per cent on 108=21 6 exactly, 19 9 per cent on 108—21 49 exactly]

201 *The ullage rod*—A simpler method, which is sometimes employed in the case of casks that are nearly full, is that of the ullage rod, a special small rod of square section by means of which the vacuity is read off at sight and deducted from the content The rod is usually graduated in gallons so as to allow for the average thickness of the staves of the three most important casks, *viz*, pipe, hogshead and quarter, the figures proper to each of the three being marked on different faces This instrument must not be regarded as anything more than a rough guide to the vacuity, its limit of accuracy averaging about ½ gallon for vacuities of less than 5 gallons, over 5 gallons the nearest complete gallon should be taken

202 *Care of instruments*—Gauging rods should be kept in a dry place when not in use The head rod and callipers should not be cleaned with spirit Slide rules should not be kept in a closed box or almirah when not in use They should be suspended from a nail in the wall of the office or warehouse If the slide does not work freely, powdered black lead should be applied liberally to the flanges

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CHAPTER X.

Wastages.

203 *Losses in manufacture or storage—periodical stock taking*—Every distiller or warehouse-keeper should be required by the terms of his license to account for all spirit produced or received, a check of which should be made at a periodical stock taking by a superior officer This should occur at irregular and unexpected intervals and not less frequently than once a quarter The stock-taking officer should check the transactions of the period, take stock of the balance and record the difference as wastage, to be written off if duly accounted for, and, if not, paid for at the close of the year

204 *Causes of loss*—The wastages chiefly met with in taking such an account are, first, losses through shrinkage, which have already been dealt with in the chapter on reduction and blending, second, special losses by accident or otherwise, which should be reported at the time they take place and should form the subject of a special enquiry, if necessary, and, third, losses by evaporation, which are those with which the stock taking officer is chiefly concerned

205 *Loss by evaporation*.—It is impossible to lay down any general scale of loss by evaporation for all distilleries in India since conditions vary so widely in respect of climate, strength of distillate, and other matters, but it may safely be laid down, first, that nature of apparatus, should never be admitted as an excuse for excessive wastage, and, second, that for all ordinary Indian distilleries, having regard to the short period that elapses between manufacture and issue, 2 per cent per annum on the transactions of the year is a sufficient maximum to allow If therefore, the wastage disclosed by the result of the four stock takings after deduction of losses due to shrinkage or special causes exceeds this limit the distiller should be called upon to show cause why he should not pay the duty on the deficiency

206 *Cautions to stock taking officers*.—It will be as well to notice here some circumstances which are apt occasionally to cause difficulty to stock-taking officers In the first place a vat or cask is sometimes found owing to the nature of the wood or the use to which it has previously been put, to cause obscuration of the liquor (*See* Appendix VII) This is not a common occurrence but the point should be remembered If an unexpected difference of strength is found or if for other reasons obscuration is suspected, a sample should be taken and sent for test at a laboratory Coloured spirits should always be regarded as possibly obscured On the other hand colourless spirit may at times be highly obscured by sugar or other additions But colourless spirits rarely if ever show obscuration due to absorption from a cask

In cases in which an officer's suspicions that salt sugar or other substances likely to affect the indications of the hydrometer have been dissolved in the spirits are not sufficiently definite to warrant his taking samples, he should from time to time evaporate a small quantity of spirits in a watch glass, when the presence of solid matter will be easily detected Vegetable substances, such as sugar may be distinguished from salt by their being blackened and dissipated by heat after the spirit and water have been driven off For this purpose, remove the residue from the watch glass and heat on a clean metal surface *e g* platinum foil or a piece of kerosene tin It is well for officers occasionally to apply this simple test even when they have no suspicions that such substances as sugar etc, have been dissolved in the spirits made in the distillery under their charge Few samples will be found which do not have some traces of solid matter after evaporation, derived from the ordinary impurities in the water used in the manufacture of spirits, but these may always be distinguished from foreign matter added in such quantities as would affect the strength indicated by the hydrometer

It is further well to remember that storage for any considerable period in a very dry hot climate is apt to cause, concurrently with a considerable loss of spirit, an increase in the strength of what remains (*See* also appendix

VIII) This is due to the facts that both alcohol vapour and water vapour pass out through the pores of the wood and that in very dry climates the percentage loss of water vapour is the greater

It is hardly necessary to add that an ascertained wastage should never be allowed to be made up by the addition of liquor from another vessel

207 *Transit wastages* —When spirit is transferred from a distillery to a warehouse, stock should be taken of it immediately on arrival so that the wastage in transit may be clearly ascertained and not confused with subsequent loss in storage The principles governing the writing off of such losses have been laid down by the Government of India as follows —

(1) The grant of an allowance for wastage should be an incident of supply in bond only

(2) Only actual wastage should be allowed

(3) Collectors and officers in a corresponding position should be allowed discretion in the matter of writing off actual wastages within reasonable limits

(4) The limits should be so fixed as to cover all ordinary cases, with reference to standards of time occupied in transit

(5) Wastages should be calculated on the contents of individual casks or vessels

(6) Wastages in excess of the limits and all wastages in exceptional cases should be referred to the Excise Commissioner or other similar officer, who should penalise only if he sees reason to suspect fraud

When there is a great difference between the temperatures at which the spirit was observed on despatch and arrival the fact should be specially noted and allowed for Under the English practice an extra allowance of 05 per cent for each degree is made in this case for contraction if the ordinary allowance is not sufficient to cover the wastage ascertained, and the temperature on receipt is lower than that on despatch *

208 *Wastages in breweries* —For wastages in breweries in which regular accounts of manufacture are kept an allowance of 5 per cent for loss in the process of manufacture may be made

* Regulations governing the receipt and delivery of and the operations allowed on dutiable goods deposited in customs or excise general warehouses throughout the United Kingdom para 189

209 *Grogging*—It should not be forgotten that, as casks absorb spirit, attempts are sometimes made to recover this alcohol by steaming the interior of the empty cask or by dissolving out the absorbed spirit with water To prevent this in one of the larger Provinces all casks are systematically treated with water by the Excise officer after they have been emptied Details of the process will be found in Appendix IX

CHAPTER XI.

Obscuration.

210 *Obscuration explained*—The strength of any mixture of spirit and water being determined by its specific gravity the addition of any soluble matter to the mixture obscures the true strength by altering the specific gravity, and the extent to which it does so is called the obscuration of the spirit, which can be measured in proof degrees or hydrometer stem degrees

211 *Cases in which it arises in Excise work*—The cases in which obscurations concerning Excise officers occur are generally four —

(1) when in the simpler types of pot stills part of the wash froths or spirts over into the receiver (priming)

(2) when the spirit takes up obscuring matter from the receptacle in which it is placed

(3) when spicing sweetening flavouring or colouring agents are added to plain spirit prior to its issue as spiced spirit or as locally made foreign spirits paying the tariff rate,

(4) when licit spirit is coloured to ensure its being readily distinguished from illicit spirit

212 *Spirit discoloured by priming*—When spirit is discoloured by the priming of the still unless the discolouration is of a very slight character, it is best to return it for redistillation at the same time taking precautions against further priming as indicated in a previous chapter

213 *Discolouration by matter in storage vessels*—The case of spirit that is obscured by matter absorbed from casks or vats has already been mentioned Such spirit may, of course also be returned for re-distillation If it is not thought necessary to do this a sample should be sent to the nearest authorised laboratory in order that the degree of obscuration may be estimated

214 *Compounded spirit*—Colouring sweetening or flavouring agents should ordinarily be added either before re-distillation when they are of such a nature as to cause no appreciable obscuration or after duty has been

paid If this is done, no necessity for testing the extent of the obscuration arises If for special reasons any other course is taken, then a sample of the spirit should be sent to a laboratory so that the extent of obscuration may be ascertained before duty is levied

215 *Licit spirit coloured to distinguish it from illicit* —When licit spirit is coloured to distinguish it from illicit it is convenient to use caramel as colouring matter, in which case the amount of obscuration resulting from the addition of a given quantity can readily be reckoned *

216 *Proper method of preparing caramel* —It should be seen, however, that the caramel is properly prepared, in which connection the following directions will be useful —

(1) Place any convenient quantity of molasses in a copper or tinned pan or *degchi*

(2) Heat over a quick fire stirring all the time, until fumes begin to come off, when the pan should immediately be transferred to a slow fire

(3) Continue heating over the slow fire, stirring all the time When the caramel making is approaching completion fumes will again come off But continue heating and stirring until the whole becomes of a deep black colour with a perfectly smooth, shining surface If heating is continued beyond this stage the caramel becomes undesirably modified, causing it to give a precipitate when added to spirit

(4) *At the completion point above mentioned, remove the pan from* the fire and add water at about 160—170 degrees Fahr, in a fine jet stirring all the time, until the desired consistence is obtained

(5) Dilution can be subsequently made to any desired degree of specific gravity below 1150° It is preferable to dilute enough for only a few days use at one time as otherwise the caramel may not keep well

217 *Cautions regarding obscuring substances* —It should be remembered that substances in solution can alone affect the specific gravity If merely suspended and not dissolved they have no effect † Sugars are by far the most important obscuring agents It is to be noted that imperfectly caramelised sugars giving only a slight colour to spirits may cause very marked amounts of obscuration Thus the degree of obscuration does not necessarily vary according to the depth of the spirit's colour But distinctly coloured spirits should always suggest some degree of obscuration Obscuration from priming of the still is usually slight Obscuration from the cask is also usually slight and due to various tannins absorbed from the wood.

* Table showing the amount of obscuration resulting from caramel and sugar solutions will be found at pages 30 [illegible] of Colonel Bedford's Notes and Reports on Technical Excise Subjects in India 1910

† But see foot note to page 62

218 *Method of testing for obscuration*—It follows from the foregoing remarks that the making of tests for obscuration seldom directly concerns Excise officers, though such tests form an important branch of work in Custom houses The process employed in the United Kingdom for the purpose, briefly, is to test a sample of given bulk with the hydrometer, then to distil it to remove the foreign matter, then to make up the original bulk with distilled water at the original temperature and to test again with the hydrometer Any difference between the two tests as shown by Sikes's Tables is the obscuration of the sample Some of the Indian Custom houses have hitherto employed a more elaborate process depending on the use of the specific gravity bottle, but the English process slightly modified for use in a tropical climate is now uniformly employed there in ordinary obscuration tests

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CHAPTER XII.

Denaturation.

219 *The necessity for denaturation*—In addition to being used for drinking spirits are largely used by the general public for various purposes and also in sundry industries which would be unduly handicapped if spirits were only obtainable on payment of the potable spirits duty To meet this difficulty strong spirits are allowed to be issued at the ordinary tariff rate of $7\frac{1}{2}$ per cent provided they are first rendered so nauseous that no one will drink them This is effected by the addition of some substance that is not easily removed, or, in the words of the tariff, the spirits are ' permanently and effectually rendered unfit for human consumption " The substance originally used for this purpose was wood naphtha or crude methyl alcohol and the spirits with which it was mixed were called ' methylated spirits " Now that that has been abandoned in India for other agents except in special cases the term ' denatured spirits " is more accurate and should be adopted

220 *The agents used*—The Agents used in England (10 per cent wood naphtha together with $\frac{3}{8}$th per cent mineral naphtha in ordinary cases, and 5 per cent wood naphtha only in special cases) are unsuitable for general use in India The practice as regards denaturation has hitherto not been uniform throughout India and the above agents and also caoutchoucine were formerly used for purposes of general denaturation Recently, as the result of exhaustive enquiries into the question Government has approved the adoption of a general denaturant which consists of $\frac{1}{2}$ per cent of light caoutchoucine with $\frac{1}{2}$ per cent of crude pyridine bases coupled with a provision that spirit issued for denaturation shall not be less than 50° O P

221 *Light caoutchoucine* —Caoutchoucine is made by the slow dry distillation of waste vulcanized rubber, and light caoutchoucine is made by the redistillation of this liquid which process has the effect of removing certain smoke causing and otherwise objectionable ingredients and which results in a *product that mixes more readily with the spirit*

222 *Pyridine bases* —Pyridine bases are made chiefly from the distillation of coal tar or shale but are not at present produced in India The use of pyridine from animal sources for purposes of denaturation is absolutely prohibited in India in order that no caste or religious prejudices may be offended

223 *Tests of suitability of denaturants* —Separate samples of either agent must be submitted for test by a Chemical Examiner or other authorised official analyst before they may be brought into use A description of the method to be followed in ascertaining the suitability of light caoutchoucine and of pyridine bases is printed as Appendix X

224 *Duties of distillery officers* —*The duties of distillery officers in connection* with denaturation are to take samples of the agents proposed to be used, to keep the stock under lock and key to issue spirit and denaturants for admixture to supervise admixture in a room set apart for the purpose and to send samples of the result for final test before issue No quantity of less than 50 gallons should be allowed to be denatured at one time

225 *Process of admixture* —In making the admixture it will be found practically convenient to add half a gallon of each denaturing agent to 100 gallons of the spirit The denaturing agents should be put into the vessel first and the spirit after being tested should be poured on them The contents of the vessel should then be repeatedly stirred to ensure that they are properly mixed

226 *Examination of spirit on sale* —Inspecting officers should occasionally examine denatured *spirit* that is exposed *for sale to* ensure that it has not been rendered potable or reduced in strength Spirit mixed with the denaturants above described reads not less than 50 O P by the spirit hydrometer has a characteristic smell and turns milky on the addition of water If any cause for suspicion is found a sample should be sent to a Chemical Examiner for complete test

227 *Special denaturants* —In certain industries where the general denaturants are unsuitable for use the use of special denaturing agents may be permitted under special Excise administrative sanction Each case will be dealt with according to its special requirements subject to general regulations to safeguard revenue interests in the matter

CHAPTER XIII.

Brewing.

228 *General description of the process*—In its widest sense, "beer" is a liquor made by infusion and fermentation from any vegetable substance Thus we have rice beers, *mahua* beers, ginger-beer, etc But with a consideration of these we are not at present concerned The class of beers which are now under notice are those known as "malt beers," that is, liquors made from an infusion of prepared barley called malt" which has been boiled along with hops and then fermented

The manufacture of beer of this class falls into five stages —

(1) Preparation of malt from barley (2) Infusion of the ground malt (grist) and straining the resulting extract (wort) (3) Boiling the wort with hops, straining off the hops, and cooling (4) Fermenting the wort (5) Settling and casking

229 *Varieties of beers*—Pale ale is usually made from the best malt and hops and is heavily hopped

Mild ale is usually alcoholically stronger than pale ale and is less heavily hopped It is also stronger in extract

Porter is a black beer It is prepared with pale amber and roasted malts in order to get its special taste and colour

Stout is a "stout" or strong porter a better quality of porter

Lager beer is prepared by a different method of fermentation, a special type of yeast being used and a particular method of storage also being employed The fermentation is carried on at very much lower temperatures, say, from 20° to 25° F below that used for ordinary beer The yeast used is different It is a smaller yeast cell and is termed bottom yeast" in contradistinction to the 'top yeast" used for ordinary beer, as the fermentation proceeds more at the bottom of the fermenting vat The fermentation also lasts much longer, from 10 to 20 days When the brewing of the beer is finished, it is stored at from 38° to 42° F for about four months It is then racked into casks and wherever possible, each day's supply is sent out fresh Lager beer contains more carbonic acid gas than the ordinary beer This fact results from the lower temperature at which it is fermented and stored

'Running ale" is the term applied to ale or beer used for consumption after having been only, say, a week or 10 days in store

Stock" ales are those stored for some time in order to develop special qualities from maturing

Strong and export ales are often kept about a year before issue and such ales are preferably brewed from waters with much permanent hardness In

export and pale ales some hops of the best quality are usually added to the task when filled so as to make the beer keep clear and sound and to improve the flavour

230 *Water suitable for brewing purposes* —It may be said that each particular type of beer requires a special kind of water, that is to say, that the water at any particular brewery will not be equally suitable for making the different types of beer above described For instance London and Dublin are famous for the porter or stout produced there and this is largely due to the kind of water available It is much softer than that used at Burton or Edinburgh for the production of ales Brewers thus frequently find it necessary to add salts to their water so as to make them suitable for particular purposes and this is of course, a perfectly legitimate and, indeed necessary practice To make light clear ales which will keep well a hard water is necessary Pale ales require a water containing between 50 and 100 grains per gallon of sulphates, carbonates and chlorides of lime, magnesium, potassium or sodium in varying proportions

The kind of water used in brewing is very important The English brewer uses a hard water—that is one which contains a large proportion of salts of lime and magnesium He chooses such a water because he wishes to dissolve out of the grain just sufficient of its nitrogen containing matter to act as a food for the yeast which is to be used later on The German brewer brews by a quite different method and prefers a soft water—that is, one with as small a proportion of lime and magnesium salts as possible This he does as he requires a large amount of nitrogenous matter to be dissolved out of the barley and a soft water dissolves this out better than does a hard water At the same time it is necessary to dissolve out enough albuminous matter to act as a yeast food during the fermentation process which follows mashing If too much albuminous matter is dissolved out, then the beer may remain turbid or "thick" thus lessening its commercial value and making it more difficult to preserve "sound"

Where a soft water only is obtainable at the brewery, a hardening mixture is added to it so as to bring it up to the required degree of hardness Mild beers require a water neither too hard nor too soft The quantities added depend of course on the chemical character of the water available and this is purely a question for the brewer Phosphates are added occasionally to the water used for brewing generally to the wort, as a food for the yeast This *practice is often necessary In any case previous Excise sanction should be* obtained before phosphates are allowed to be added

At times it has been alleged that sodium chloride (common salt) has been added to the water with a view to make the beer salt in taste and so more thirst provoking This is of course, a practice that should never be permitted

as it tends to increase consumption unduly and by improper means Where there is reason to suspect any such practice samples of the brewing water and of the beer made with it should be sent for chemical analysis and report

231 *Preparation of malt*.—The use of good malt is essential to successful brewing In India and European countries barley is the favourite article from which to prepare malt This is due to the fact that barely contains the proper chemical constituents to produce rapidly during germination more than a sufficient amount of ferment (diastase) to convert the unfermentable starch in the grain into fermentable sugar Barley also germinates more quickly than other cereals Malt barley is also free from the oily unpleasant taste which other malted cereals are found to give to beer Another advantage of barley is that the essential growing part (called the acrospire) lies inside the husk, and not outside as in maize and wheat, and it is thus less liable to injury. The art of choosing a good quality of barley for malting can only be acquired by practical experience of samples and is in any case not a question of special Excise interest Barleys are in England classed as "heavy barleys" which weigh from 54 to 58 lbs per bushel and light barleys," weighing from 48 to 52 lbs per bushel Each kind of barley has its special advantages and disadvantages A skilful brewer selects and blends his varieties of barleys so as to obtain the right proportions of extractive matter

232 *Malting*.—The barley has next to be malted In this process there are four stages —(1) Steeping (2) Couching (3) Flooring, and (4) Kiln-drying

233 *Steeping*.—The grain is steeped in water for a time varying from 48 to 96 hours according to the kind of barley used and other considerations In Bavaria, 72 hours is the usual time while in England and Vienna 48 to 50 hours is the rule The water is run off and renewed every 24 hours in order to keep it as fresh as possible The brewer knows that the grain has been sufficiently soaked when its skin easily peels off and when each grain can be readily bent and crushed when squeezed lengthways

234 *Couching*.—The water is next drained away and the barley placed on the malting floor—either on the floor itself or less frequently now on a rectangular frame called a 'couch' The barley is spread out in a layer about a foot deep usually, but often much deeper In this way the process of "sprouting" or germination is allowed to proceed Germination turns the barley into malt A grain of barley contains a germ or embryo and also a sufficiency of food to feed the embryo This food is not in a fit state for consumption by the embryo until it has been prepared by certain ferments present in the grain These ferments begin to act when sufficient air, water and suitable heat are applied Then the ferments start work and change the

food stuffs in the grain from insoluble substances to others which are soluble and diffusible and thus fit for the embryo's nourishment The brewer checks this process at the point which suits him best, that is to say, he wishes to get as much ferment formed as will (1) turn the starch into malt sugar and dextrin, and (2) change the albuminoids present into good yeast food The substances which are formed when barley changes into malt are termed "diastases" or "diastatic ferments"

The stage of couching is generally allowed to last about 24 hours, but this period is varied according to the temperature prevailing The barley is usually turned about every 6 hours while on the floor or couch so as to expose all parts equally to air moisture and an even temperature

235 *Flooring* —When the grain begins to germinate or sprout the couch is broken down and the barley floored' that is spread on the couch in thinner layers, which are turned with a shovel about twice daily so as to expose all the malt equally to air and moisture The depth of the layer is determined by the rapidity of germination and by the air temperature, which is regulated by letting in cooler or hotter air as required Plenty of fresh air is needed for good germination The amount of water sprinkled on the grain has also to be carefully regulated The lighter kind of barley malts more rapidly than the heavier

236 *Kilning* —The malt is next sent to the drying kiln for three or four days The kiln is generally a square building with two floors made of wire cloth An open fire is kept burning at the foot, and there is at the top a large ventilator The malt is placed on the upper floor for a time and is then removed to the lower floor where the temperature is higher Thus germination is stopped and the moisture is removed from the malt, which is now ready for use

237 *Malt substitutes* —The practice has arisen in various countries of substituting a proportion of sugars or starches for malt and these are called malt substitutes or malt adjuncts They are specially used when brewing the more modern types of light ale In India up to the present, malt substitutes have not been used to any very considerable extent, except in breweries that cater for the native markets in Southern India In England, no attempt is made by the Government to limit the proportions or varieties of malt substitutes so long as the substitute used conforms to certain estimates of extractive value as compared with malt Thus 256 lbs of glucose or saccharum or flaked rice are considered equal to 1 quarter of malt Again 224 lbs of cane sugar or any sugar in crystals or of caramel is taken as the equivalent of 1 quarter of malt *Again 272 lbs of syrups which weigh 11 lbs to the gallon* are taken as equal to 1 quarter of malt In Southern India it has been found necessary to prescribe the minimum proportions of malt and hops to be

used in order to prevent the sale as beer of what is nothing more than a sugar wash The proportion laid down is not less than two bushels of malt per hogshead, which gives a specific gravity of about 1037°

238 *Hops*—Hops are used on account of (1) the aromatic bitter taste they give to beer (2) their preservative properties, and (3) their clarifying action The ripe female flowers of the hop plant (*Humulus lupulus* of the natural order *Cannabinaceæ*) are the parts used in brewing The resins and oils give the bitter flavour and preservative action The aromatic flavour is mainly caused by the volatile oil The hop tannin precipitates albuminous and other substances and clears the beer Lupulin is the granular brownish yellow powder, called hop flour, found in all hops, but varying considerably with the variety of hop, and in different crops of the same variety The lupulin contains most of the active constituents of the hop, i.e., volatile oils resins and bitter substances The quantity of hop flour or lupulin present is roughly ascertained in practice by the amount of stickiness resulting when the hops are rubbed between the hands The bitter in hops is distinctive It differs from almost all other bitters in that its bitter taste disappears at once after a beer which has been flavoured with hops has been swallowed With other bitters the taste lasts much longer

Hops are almost wholly imported into India, though some attempt has been made to grow them in Chamba and Kashmir

239 *Hop substitutes*—Hops at times have been replaced to a greater or less extent by substitutes such as quassia, gentian, calumba, chiretta, *cocculus indicus*, camomile, strychnia, aloes, marsh trefoil, broom, wormwood, grains of Paradise, opium, tobacco, various catechus, darnel, picric acid, etc The first four of these are harmless bitters but the use of the other substances mentioned is not permissible Certain so called hop-substitutes are used merely as sources of tannin in order to "clear" the beer No bitter is as good as hops None has its special flavour or its other advantages as a preservative and clarifying agent The use of hop should, therefore, be as far as possible encouraged It is the best agent to use from every point of view In certain cheaper types of beer made in India a proportion of hop substitutes is often used along with hops As long as the substitute is a wholesome bitter there is no great reason to object to this, but it should always be borne in mind that no substitutes can effect such good results in the manufacture of beer as hops For the above reasons in the Southern India breweries above referred to a minimum of hops as well as of malt is prescribed for the inferior qualities of beers For the purpose of this regulation, partially exhausted hops are also allowed to be employed, the proportions being 2 lbs of hops to a hogshead 2½ lbs of partially exhausted hops being reckoned equal to 1 lb of fresh and 20 per cent of substitutes being allowed. But at least 1 lb of fresh hops must be used

240 *Mashing*—The process used for beers of English type is known as the infusion process, and that used for beers of the German type as the decoction process

The following is an outline of the former method —The malt is first crushed by rollers in order to make its contents more readily soluble and this crushed malt is termed "grist" The grist is removed (by elevators) to grist-cases or "hoppers" in connection with which are shoots or funnels by which it can be run into the mash tun On its way to the mash tun it is mechanically and gradually mixed with hot water by the aid of a revolving machine The mixture enters the mash-tun of a thick consistency somewhat like porridge. The amount of hot water required for a given amount of grist is calculated so that the amount of wort obtained can be carefully regulated

During mashing the production of alcohol producing material and of characteristic flavouring substances is aimed at If the proper beer flavour is to be obtained, a certain amount of malt must be used—not all malt necessarily, but a sufficient amount of malt A small amount of malt will, under suitable conditions convert the starch of a large quantity of unmalted grain According to the alcoholic strength and kind of beer aimed at, the proportions of malt-sugar (maltose) and dextrin vary For an alcoholically strong beer of little body and one which is not to be stored but is to be rapidly consumed, little dextrin and much maltose is required For export beer or stout, much dextrin is needed in order to prevent the beer turning too acid and also in order to keep it brisk, *i e*, sparkling or aerated

After mashing is complete the tun is covered so as to prevent loss of heat during infusion It is at this stage that the diastase ferments change the unfermentable starch into the fermentable substances malt sugar (maltose) and dextrin

After standing for about two hours the mash is slowly drained off through the perforations in the false bottom of the mash tun by opening the taps

The residue has now to be washed out by a process termed "sparging" This is done by spraying hot water gently on it by means of a revolving pipe pierced on its alternate sides The weak liquor in the tun is then drained off and the residue of grist thus left is termed "brewer's grain" or "draff" The extract from the grain is called the wort and the amount got from any one fermentation is called a "gyle" The wort is now run into the coppers where it is mixed with hops and boiled for about two hours After being boiled in the copper, the wort is passed into the hop-back ("drainer") where the hops are strained off, the wort passing through the perforated false bottom to the "cooler," or other refrigerating plant The cooler usually consists of

a series of large shallow vessels From these the wort passes to the "refrigerator" which consists of a series of flat copper pipes through which cold water passes The hot wort flows over the outside of these pipes and is cooled Here, as in the condensing worm of a still, the current of hot wort flows in one direction and that of the cold water in the opposite so that the wort as it cools constantly meets colder water while passing over the refrigerator From the refrigerator the wort flows to the fermenting tuns, and it is at this stage that various brews having different specific gravities may be mixed so as to obtain a wort of any required gravity previous to fermentation The rate of flow to the fermenting tuns is regulated according to the temperature at which the wort is to be treated with yeast (pitched) The last is a particularly important point as on it largely turns the success of the fermentation The temperature employed varies according to the type (weak or strong) of the beer to be produced

211 *Pitching the wort*—Yeast in suspension is next run into the wort The amount used varies according to the strength of the yeast and of the type of beer required From 1 pound to 5 pounds or so of good thick, stiff yeast per barrel is about the range 1½ to 2 lbs of yeast per barrel for a beer of 18—20 lbs gravity * brewed with between 5 and 6 lbs of hops per quarter of malt, may be taken as an average example Again, a 24 lbs wort with 14—16 lbs. of hops per quarter will need 2½ to 3½ lbs of yeast per barrel When the yeast is added to the wort, fermentation commences and the liquid begins to bubble and a gradually thickening brownish frothy layer forms at the surface A few hours later fermentation is at its height and in well under two days time it is completed in many cases though in some Indian breweries it goes on for five days or so The wort is then run off into "fining" vessels so as to settle and clarify as the yeast cells left behind fall to the foot of the vessel Throughout the fermenting stage the wort's temperature is regulated by coils of piping (called "attemperators") through which water of a suitable temperature is passed

212 *Racking*—After this and when sufficiently bright, the beer is run off ('racked) either into store vats, casks or bottles for issue

213 *The English method of levying duty on beer*—In the United Kingdom the duty is levied in proportion to the original gravity of the wort Relatively speaking the Excise control of breweries is much less stringent than in the case of distilleries No Excise locks are used The constant presence of an officer is only considered necessary in the case of very large breweries working continuously The safety of the revenue depends on notices of all essential operations which are required to be given to the Excise The length of notice to be given depends on the importance of the particular operation

* Note — 18 to 20 lbs gravity i e a barrel (36 gallons) of such beer weighs 18 to 20 lbs. more than the same volume (36 gallons) of water

and on the facility with which the local officer can attend One officer is, in general, in charge of a group of the smaller breweries

A brewer must give timely notice of—

(1) his intention to brew,

(2) the nature and amount of materials to be used,

(3) the time at which he expects his mash tun to be drained (this is to enable the officer to take a dip of the drained grains, which must lie for 2 hours after draining or until the officer arrives),

(4) his intention to mix the products of one or more brewings,

(5) any modification in his routine methods of brewing,

(6) any alterations he proposes to make in the position, etc, of his brewing vessels

(7) Finally and most important of all, the brewer is required to give notice to the officer of his intention to "collect beer," i e, he must intimate as closely as possible the time when the wort will be ready for pitching with yeast When the wort is collected for fermentation the brewer must forthwith take the specific gravity with his saccharometer and also the dip, in order that the density and gallonage may be recorded in case the officer does not attend In cases where the officer attends before fermentation has materially affected the gravity he is able to verify these figures, and above all to see that they have been recorded properly by the brewer

In order that his control may be effective, the officer must time his visits to the brewery so as to arrive when fermentation has not advanced too far for check, and so that the brewer has had reasonable time to make his entries of gravity and gallonage If, having had reasonable time the brewer has failed to make his entry this omission is treated as a serious Excise offence

It may be asked why stress is not laid on the necessity for the attendance of the officer at the time of pitching the wort This, however, is generally impracticable, seeing that usually brewers "collect beer" at the same hour and that the presence of the officer at more than one brewery is impossible This being so, his visits must be unexpected, the responsibility for honest declaration of gravity and dip being imposed on the brewer The brewer's records, if confirmed by the officer, are thus the basis on which the duty is levied Where the officer finds it necessary to increase the gravity or gallonage his figures are used for levy of duty If the officer's figures fall short of the brewer's (as happens for gravity when the officer's visit has been delayed) then the brewer's figures are to be accepted—any obvious error, of course, being corrected at whatever stage it may be detected As

regards the dip, no difficulty arises as all vats are accurately gauged If any addition of sugar has been made to the wort after fermentation has proceeded to, say, 20 or 30 degrees from the original gravity, a check can always be applied by taking a sample for determination of original gravity at an Excise laboratory A further check on the brewer's operations consists in calculating the yield in standard gallons (at gravity 1055°) that he may reasonably be expected to produce from the materials used and by his method of working This is known as the "materials' charge" It is occasionally found necessary to levy duty on this if no satisfactory explanation of low output is forthcoming The materials charge is calculated at the rate of 36 gallons of wort of gravity 1055° as obtained (*a*) from 84 pounds of malt, or (*b*) from 56 pounds of sugar

214 *The Indian method*—Where these methods of control have not yet been worked up to in India, duty is charged on the number of gallons issued, brewer's accounts being accepted subject to periodical stock taking In Madras, Bombay Bengal, Central Provinces and the Punjab, however, the main features of the English system have been introduced and duty is levied on the quantity manufactured

215 *Preservatives*—Hops are the natural preservatives of beer, but in addition to these, especially where beer has to be exported or kept for some time before consumption certain chemicals are added, usually when the beer is racked but also when in the store vat or issue cask Those nearly always used consist of preparations containing sulphites, and known as bisulphite of lime, calcium sulphite potassium metasulphite ("K M S"), "Berne s Nos 1 and 2," etc Sulphites become gradually changed in the beer into sulphates, which have no preservative action Sulphites cannot be said to be an altogether wholesome addition to beer, as experiments made in various countries show that they are not harmless substances—even in the small amounts in which they are found in beer They seem, however, to be least harmful preservatives in use It is unnecessary to require a declaration from the brewer that sulphites have been added to beer as the practice is permissible and is an almost universal trade custom Nor is it necessary to prescribe a limit of quantity If the brewer knows what quantity is sufficient for his purpose he will not, of course, add any more than is necessary because of the cost and also because the beer, if over sulphited, acquires a disagreeable smell and taste of which the consumer soon complains An extensive series of analyses made at the Central Excise Laboratory has shown that in no case had an excessive amount of sulphites been added to the samples of imported or Indian made beer which were examined

No other preservative than sulphites should be allowed to be used unless under special sanction from Provincial Excise head quarters.

246 *Secondary fermentation*—When sound beer is vatted or casked for any time a very slow natural fermentation takes place This secondary fermentation when normal is of value as producing constantly carbonic acid which keeps most of the disease ferments of beer in check Thus the process promotes stability of the beer, and helps to give it the sharp, stinging taste which is valued by most consumers The modern tendency is to produce less ripe and mature ales so that storage for maturation is very often reduced in time or even omitted altogether Sometimes, however, the secondary fermentation becomes too violent and the beer is then said to "kick up" or "fret" This last is a sign of faulty manufacture or handling

247 *Fining*—Where beer is quickly consumed insufficient time for clarification is a difficulty To obviate this suspended matters are removed from the beer by means of finings, of which the commonest and best is isinglass From 2½ to 3½ pounds, according to quality, is needed for each 36 gallons of beer Finings should be added to the casks of beer immediately before they are sent out

248 *Dry hopping*—A small amount of fresh hops of best quality is frequently added to beer at the time of racking, about ½ to 1 pound per barrel according to circumstances By this means an extra flavour and aroma and also better keeping and clarification are obtained

249 *Sourness of beer*—No beer should contain more than ½ per cent (or 350 grains per gallon) of total acid, calculated as lactic acid, whether in the free or combined state Beer that is very sour to the taste should be sent for analysis

250 *Colouring agents*—Caramel or roasted or high cured malts should alone be allowed to be used without special sanction Such colouring agents should be added to the beer before duty is levied

251 *Alcoholic limits*—Beer is more lightly taxed than spirits because of its usually low alcoholic strength and because it is also regarded as, in part, a food It is not really so much a food as a food adjunct—that is, a substance which supplements diet The nutritive constituents of beer are comparatively small in amount and consist of the extractive substances obtained from the malt The hop bitter in beer in many cases has also a beneficial action in stimulating appetite, thus indirectly assisting in improving nutrition

Beer varies in alcoholic strength from 1 per cent by volume (below which no fermented liquor is usually taxed) up to 8 5 per cent by volume in the case of certain strong ales But beer of the general types should not exceed an alcoholic strength of 7 5 per cent by volume, which corresponds to an original gravity of about 1068°

252 *Limits of specific gravity*—As has previously been explained, the English duty on beer is fixed for a standard gravity of 1055° and the duty on each brew is arranged with reference to this In other words

the duty levied is roughly proportionate to the strength of the beer In India where duty is levied simply on gallonage it is advisable to supplement this by regulations limiting the strength to a certain maximum Limits of this sort may be imposed on original gravity or on final strength the former being the easier to enforce Limits which have been imposed at breweries in Southern India are Maximum initial gravity 1073° and maximum strength 8 per cent alcohol by volume

253 *Watering of beer*—Water is the chief adulterant of beer The rule that no water should be allowed to be added to beer after duty has been assessed should never be departed from The method of detecting the watering of beer is to compare the original specific gravity of the beer—if recorded of imported beer at the Customs and of Indian made beer at the brewery—with the original gravity as found by analysis The fact of dilution will then be at once evident

254 *Arsenic in beer or beer materials*—Less than 1/100th of a grain of arsenic (expressed as arsenious anhydride As_2O_3) is the maximum amount allowable per gallon in beer or per pound in solids such as malt invert sugar, glucose etc used as beer materials This is the limit fixed in accordance with the recommendations of the Royal Commission on Arsenical Poisoning held in 1903 No cases of arsenic poisoning from beer have yet come to light in India

255 *Foam producers*—In certain cases small amounts of chemicals (chiefly saponins) are added in order to give a good foam or head' to the beer Quillaia bark m ... and pale heading powder are some of the substances used There is no satisfactory evidence to show that these substances in the small quantities used in beer have any deleterious effect

256 *Priming*—Priming is the addition of a strong solution of sugar or of cold water malt extract to the cask of beer just before it leaves the brewery especially when it is to be quickly consumed Slight gradual fermentation results and keeps the beer brisk The practice is permissible but, in cases when duty is levied on issues only before duty is assessed, and only in amounts not exceeding 1½ per cent of the beer to which the primings are added The specific gravity of the priming solution should not exceed 1150° Priming solutions should be kept in a separate vessel properly gauged and marked

CHAPTER XIV.

Country Beers

257 *Tari or toddy*—Tari is the fermented or unfermented sap of any kind of palm tree

258 *Palms tapped* —The palms most commonly tapped are dates and palmyras Cocoanut palms are also extensively tapped where they occur. Palms of which the tapping is less common are the bastard sago, the *dadasal* (*Arenga Wightii*) and the *dhani* (*Nipa fruticans*)

259 *Method of tapping* —The method employed in extracting the sap of palmyras and cocoanuts is to cut off the end of one of the flowering shoots and bend it over into a collecting pot A fresh slice is cut off every day and the shoot bruised with a wooden hammer or pair of crushers to draw out the sap In the case of date palms a portion is cut out of the stem of the tree itself and the sap running down is guided into the pot by a leaf or wooden peg inserted in the incision

260 *Precautions against destruction of trees* —Care should be taken in tapping date palms to see that the life of the palm is not endangered by the tapping operation or through the exposure of a soft surface to the ravages of white ants, crows, rats or squirrels or of the palm weevil (*Ryncophorus ferrugineus*), which is the most destructive of all The method of making the incision varies in different provinces In Madras a horizontal cut is made immediately under the apex of the palm and a triangular section, which grows deeper with each day's tapping, is taken out below it This is sometimes divided into two by a ridge left for support of the apex In Bombay a comparatively narrow section passing from below upwards, is scooped out to one side of the centre of the stem In Bengal the incision extends half way round the trunk, but it is much shallower than in Madras or Bombay and, unlike the Madras incision, has the broadest portion at the base Experience shows that the Bengal process is much the least destructive of the trees There is room for much improvement after scientific enquiry, in the processes of tapping Meanwhile, to prevent the destruction of trees belonging to Government, it is desirable that the following precautions should be observed —

(*i*) No incision should be made at any point within 4 feet of the ground or 1 foot from the base of the central whorls or 18 inches from the top of any other incision

(*ii*) The incision should not be cut to a greater depth than one third of the diameter of the tree

(*iii*) No tree should be tapped oftener than in alternate years or for more than six months in the year

(*iv*) The tappers should leave not less than eight leaves on the top of the tree in addition to the central whorls springing from the head of tree

261 *Seasons of yield* —While cocoanut *tari* can generally be obtained all the year round the yield of palmyra and date *tari* is limited to a season This

is generally October to March for dates, and April to June for palmyras, but the period of yield varies largely in different parts of India

262 *Quantity of yield*.—The quantity of *tari* yielded by different classes of trees varies enormously in different localities The result of a series of experiments conducted in Madras in 1890 91 showed that the average annual outturn of a cocoanut was 70 gallons and that of a palmyra or date palm 27 gallons. Bombay observations made between 1883 84 and 1897 98 indicated that in that Presidency a palmyra yielded as much as a cocoanut and that the average annual yield for either varied from 90 to 111 gallons Observations made in Bengal in 1894 95 showed an average yield of 43 gallons for male and 57 for female palmyras in their best season and of 20 to 25 gallons for dates

263 *Alcoholic strengths*.—The alcoholic strength of *tari* varies according to the nature of the palm tapped the season of the year, the time for which it has been drawn and other circumstances The average results of a number of tests made with toddy from *all* parts of the Madras Presidency were —

		Per cent by volume
Cocoanut	85 7 U P	8 1
Palmyra	90 8 U P	5 2
Date	91 4 U P	4·9
Sago	89 6 U P	5·9

Tari exposed for sale in Bengal in 1909 was found generally *to range in* alcoholic strength from about 93° to 94° U P When reasonably fresh it has a food value somewhat comparable with that of well made malt beer

264 *Fresh tari*.—'Fresh' *tari* is the name given to *tari* that is freshly drawn which is popularly supposed to be non alcoholic and to have wholesome properties It is to be observed, however, that *tari* ferments very easily and commences to do so very quickly both because the state of solution is favourable to rapid fermentation and by reason of the fact that the pot in which the juice is drawn is almost invariably coated with old ferment The rate of progress of fermentation varies with the kind of palm tapped and the temperature It has been ascertained as the result of an exhaustive enquiry that the only cases in which alcohol is not present are (1) when the temperature is below 60° F, (2) when a new or smoked pot has been used on a tall tree, (3) when chemical means have been used to arrest fermentation. For practical purposes, therefore, it may be taken as established that unfermented natural *tari* is not obtainable A series of tests of what [illegible] as "fresh" *tari* showed an average strength of 94° U P

265 "*Sweet*" *toddy*.—"Sweet" toddy is the name given to *tari* whose fermentation has been arrested by the addition of lime This is used [illegible]

for drinking and for sugar making and its use is at present confined to the Madras Presidency The lime may be placed loose in the pot or, preferably, as a thin paste coated over the inside

266 *Adulteration of tari*—The greatest difficulty of the *tari* administration in the Madras Presidency, where a tree-tax is in force, is the admixture of sweet *tari* which has paid no tax, with fermented *tari* from taxed trees which rapidly sets up fermentation in the sweet *tari* The Madras Government holds that the presence of lime to the extent of ten grains per gallon is sufficient proof that such adulteration has taken place The exact amount of lime present can only be ascertained in a laboratory

A similar fraud that needs to be guarded against where taxed toddy is still used for distillation is the addition of sugar for the purpose of increasing the output This may, if the increase is large, be detected by the taste, but a saccharometer test is also useful Any fermenting sample showing a gravity of over 1030° should be regarded as suspicious and sent for analysis

267 *Other uses of tari*—In addition to its use as a beverage and for distillation *tari* is also used for making sugar, for which purpose it is evaporated, and for making vinegar and bread Sugar making is the most important industry and is carried on largely in Madras and to a less extent in Bengal and Burma

268 *Pachwai and its congeners*—Another class of country beers, made generally from rice or millet, but sometimes from *mahua*, *gur* and other bases, corresponds in its nature to the Japanese *saké* and is known in India by the generic name of *pachwai* A variety of local names for these liquors has been given in Chapter I

269 *The fermenting agent*—The remarkable feature of these liquors is the use of a fermenting and malting agent until recently unknown to Western science This is known variously as Chinese yeast, *bakhar*, *muli*, *ranu*, *sonti mandu* and by other names and is supplied by the makers in small balls of a dried paste The process of making these is variously described, but the ingredients generally include a variety of spices, roots, bark, etc, pounded up and made into a paste with rice meal and ripened in straw Their action consists first in converting the starch present into sugar through the agency of certain microscopic moulds present, which have been termed *Amylomyces Rouxii*, and second in converting the sugar into alcohol through the agency of yeasts present The result is the production of as much as 22 per cent of alcohol by volume as against the usual limit of 13 to 15 per cent These yeasts have been introduced into distilleries in Europe as part of a process which is known as the amylo process

270 *Pachwai manufacture*—The agent above described is broken up and added ordinarily to rice or millet which has been husked and partly or

wholly boiled or else pulped and soaked in running water Fermentation is then allowed to proceed for from two to six days or more when a small quantity of strong liquor will be found to have formed This is either drawn off and drunk plain or diluted or left in the grain and sucked up from it by means of a pipe Like the Japanese *saké* the liquor is stated to be best drunk warm The strength of the diluted liquor varies from about 75° to 93° U P and the average may be taken at about 85° The nutritive value of these liquors is comparatively insignificant, while they have a tendency to high acidity, resulting from crude and dirty processes of manufacture and over prolonged fermentation This fact is often a cause of dysentery and other allied ailments

271 *Excise control* —Excise control is limited in the case of such liquors to the prevention of illicit manufacture and to seeing that shop manufacture is cleanly conducted and that as good water as possible is used and that no dhatura, aconite nux vomica or other poisonous ingredients are mixed with the liquors or kept on licensed premises The occasional submission for analysis of samples of the liquor and of the fermenting agent used will assist towards these ends

APPENDIX I.

Theory of the saccharometer.

A saccharometer, when floating in a liquid, displaces a volume of liquid equal to its own submerged portion, while the weight of the displaced liquid is equal to the weight of the saccharometer itself The indication of an accurate saccharometer, when divided by 1000, should give the true specific gravity of the liquid in which it floats, i e, the ratio existing between equal bulks of the liquid under test and of water

The specific gravity of Bates's saccharometer when floating at the zero* mark and with the 1,000 poise attached is 1 000 which figure represents also the specific gravity of the liquid If the density of the liquid is increased to say, 1,020 the instrument will if accurately graduated, rise in the liquid until it indicates 1 020 The volume of liquid now displaced is less than before and so the sensitiveness of the saccharometer is diminished For this reason the graduations of the stem slowly decrease from 0 to 30 (the extreme range) in order to accommodate this loss of sensitiveness, and to secure the accuracy of the readings at all points of the stem If the density of the liquid is now further increased to 1,030, an accurate instrument will float at the 30 division of the stem, and if the 1,000 poise be replaced by the 1,030 poise the liquid will cut the stem at the zero mark In order that the transition from the 1 000 poise and the 30 division reading to the 1,030 poise and the zero division reading shall be absolutely accurate, the bulk of the 1 030 poise must be made equal to the bulk of the 1,000 poise *plus* the bulk or volume of the stem itself Again the weight of the 1,030 poise must be equal to the weight of the 1,000 poise *plus* the additional weight necessary to sink the saccharometer to the zero mark in a liquid of specific gravity 1 030 The additional weight referred to above is clearly greater for the transition 1 030 to 1 060 than for the transition 1,000 to 1,030 as the former liquid is denser Thus if, say, 2 grams are to be added to the 1,000 poise (suitably increased in bulk) in order to make the 1,030 poise, about 2 1 grams will represent the excess of the 1,060 poise over the 1,030, while as much as 2 3 grams may be required to effect the transition from 1,090 to 1,120 Again it has been stated that the successive poises increase in bulk by the stem s volume, but as the material, brass, is about 8 times as heavy as the average liquid tested, it further follows that the increase in weight of the poises is small compared with their increase in bulk, in spite of the fact that the stem

* That portion of the stem extending above the zero mark must not be considered

itself is often specifically lighter than water Consequently the specific gravity of the various poises falls as their denomination increases

A rough idea of the amount of this change in specific gravity is given by the following example —

Denomination of poise	Specific gravity
1,000	5
1,030	4
1,060	$3\frac{1}{2}$
1,090	$3\frac{1}{3}$

Mixing of liquids of different specific gravities.

In calculations connected with the mixing of wort or wash, only the degrees of gravity above or below 1,000 are concerned All the problems deal, in essence, with 5 terms of which 4 are known or can be inferred

The 5 terms are —

(1) The specific gravity minus 1,000 of the first component
(2) „ „ second „
(3) „ „ mixture
(4)& (5) The bulk of both components, or, what is the same thing, the bulk of the mixture and of one of the components

No contraction occurs on mixing and so the following equation will solve all cases $(ag+a'g')= AG$ or $(a+a')G$

where a is the bulk and g the (gravity—1,000) of the 1st component.
a' „ g' „ 2nd „
A „ G „ mixture

Example I —

200 gallons at 1060° are to be reduced to 1010° with water How much water is required ?

$$\left.\begin{array}{l} 200 \times 60 = 12{,}000 \\ x \times 0 = 0 \end{array}\right\} = (200+x)\ 40$$

$$12{,}000$$

$$8{,}000 + 40x = 12{,}000$$

$$\text{Therefore, } x = 100 \text{ gallons}$$

Example II —

300 gallons at 1040°, 100 gallons at 1020° and 200 gallons at 1030° are to be mixed What is the result ?

A new pair of terms (call them a″ & g″) are introduced

$$300 \times 40 = 12{,}000$$
$$100 \times 20 = 2{,}000$$
$$200 \times 30 = 6{,}000$$

$$600x = 20{,}000 \text{ whence } x = 33\ 3$$

Result 600 gallons at 1033° 3

Example III —

What quantity of wort at 1070° will raise 500 gallons at 1030° to 1060°?

$$\left.\begin{array}{l} x \times 70 = 70x \\ 500 \times 30 = 15{,}000 \end{array}\right\} = (500 + x)\ 60$$

$$15{,}000 + 70x = (500 + x) \times 60$$
$$= 30{,}000 + 60x$$
$$10x = 15{,}000$$
$$x = 1{,}500 \text{ gallons}$$

Example IV —

Two washes are to be mixed just prior to distillation The specific gravity of one is 995° and its bulk is 100 gallons How much wort at 1007° must be added to obtain a gravity of 1004°?

$$\left.\begin{array}{l} 100 \times (-5) = -500 \\ x \times (+7) = +\ 7x \end{array}\right\} = (100+x) \times (+4)$$

$$7x - 500 = (100 + x) \times (+4) = 400 + 4x$$

$$3x = 900 \quad x = 300 \text{ gallons}$$

APPENDIX II.

(a) Directions for preserving samples.

1 The best way to preserve fermented wash during transit for analysis is to "pasteurise" it, as is done in the case of wines and beers, as follows —

A beer or champagne quart bottle half full of the wash is closed with a sound cork securely wired down The bottle is then placed up to its neck in water and slowly heated to 160° Fahr It is kept for half an hour at this temperature and then allowed to cool and should then be packed and despatched by passenger train as soon as possible The bottle must not be uncorked after the heating

The heating can be done in a kerosene tin filled with water and the bottles should be slung to a piece of wood placed across the top of the tin, so that they do not touch the bottom of the tin

If the temperature is not allowed to rise above 160° Fahr, there is no risk of bursting the bottle

2 A simple method is to add one anti fermentation powder (consisting of 25 grains of salicylic acid) to each bottle of sample Shake the bottle carefully for about five minutes keeping the hand lightly over the mouth then cork and seal as usual

(b) Directions for packing brass hydrometers, saccharometers, etc.

1 In the case of brass instruments with detachable weights, these should be wrapped up in tissue paper and made into a separate packet

2 A sufficient amount of cotton wool or soft paper should be placed over the instrument in the case to prevent any risk of displacement in transit

3 The case should then be packed in a wooden or tin box The space between this outer case and the instrument box should be sufficiently packed with paper shavings, sawdust or other suitable elastic packing

4 In the case of brass instruments, the packet containing the weights should be placed in the space between the outer and inner cases

5 The thermometer must be packed separately in a tin cylinder as described under (c)

(c) Directions for packing glass hydrometers.

1 Each stem should be packed in a separate cylindrical tin case whose diameter is about one inch greater than the width of the hydrometer's bulb, and at least one inch longer than the hydrometer stem

2 *(a) The tin case should first have some cotton wool placed in it to a* depth of an inch

(*b*) The hydrometer should then be gently placed in the case, bulb uppermost (not pushed down through the cotton wool to the foot of the case)

(*c*) It should then be thoroughly packed round with dry sawdust, not rammed too tightly, allowing equal distances all round between the bulb and the case

(*d*) The case should then be filled with sawdust to within half an inch of the top This remaining half inch should be filled with cotton wool

(*e*) The cap should then be put on without undue force and securely fastened A loose cap should not be used

3 The tin cases should then be packed in a wooden box large enough to allow of each case having a good layer of sawdust to separate it—

(*a*) from neighbouring tins, and

(*b*) from the sides and ends of the box

4 The thermometer should be packed in the same manner

5 Glass hydrometer stems should be lifted from the wooden box by the larger bulb and not by the narrow stem If the bulb is at all tightly jammed in the box and the stem is used to try to raise it there is much risk of breakage

APPENDIX III.

Scotch Whiskey Manufacture.

Pot still whiskey is commonly made in Scotland in the following stages —

(1) *Mashing to prepare the wort*

(2) Fermentation of the wort to prepare the wash

(3) Distillation of the wash to separate the spirit

Mashing—Barley malt only is usually employed The malt or mixture of malt and grain is crushed and extracted with hot water The starch of the grain is thus turned into sugar by means of the diastase of the malt The liquor from the mashing process is called wort

Fermentation—The wort is drawn off cooled and placed in fermenting vats Yeast is then added and the alcoholic liquor resulting is termed the wash

Distillation—(*a*) The wash is placed in a wash still and distilled The distillate is called low wines and what remains in the still is run to waste, being called pot ale or burnt ale

(*b*) The low wines are then placed in a smaller still known as the Low Wines Still and again distilled—

the first runnings are called foreshots

the second runnings are called clean or finished whiskey, and

the third runnings are called feints

The residue in the still is run to waste being termed spent lees The first and third runnings (foreshots and feints) are mixed and added to the low wines of a following distillation The feints from the last distillation of the season are kept to be added to the low wines of the first distillation of the following season The pot distilling season lasts from November till May Patent stills are worked throughout the year In Indian distilleries the terms foreshots feints etc are also used but they may be applied to fractions of a single distillation or to those resulting from a second distillation Much Indian spirit corresponds to the low wines of European manufacture

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APPENDIX IV.

Contraction of alcohol and water.

When 54 volumes of alcohol and 49 7 volumes of water are mixed, the result is exactly 100 volumes (*see* Chapter VIII) that is to say, 103 7 *separate*

volumes, as measured separately, contract to 100 volumes when mixed, and 3 7 volumes of water disappear or become hidden in the process As then 100 gallons of 54 per cent by volume spirit really contain 103 7 gallons, the ratio $\frac{103\ 7}{100}$*, or, more simply, the factor 1 037 gives by direct multiplication the separate gallons contained in any other quantity of spirit of this strength

In a similar manner the factors for calculating the separate volumes in spirit of all other strengths have been found by experiment These are shown in the appended table for strengths from 70° O P to 70° U P, so that the separate volumes in any spirit likely to be met with can be very quickly determined

Calculations in connection with reduction and blending operations are commonly made with reference to the alcohol only, and the ordinary rules make no provision for the effect of contraction The true quantity of water required by these rules may be readily found by the method of separate volumes It is only necessary to subtract the separate volumes of the spirit to be reduced from those of the reduced spirit, as calculated by the ordinary rules, and the result is the true amount of water required to give the calculated result free of contraction error Any difference between this and the amount calculated by the ordinary rules represents water which disappears by contraction and is a measure of the contraction error or shrinkage Similarly in blending operations a comparison of the separate volumes of the spirits blended with those of the calculated blend shows the amount of water required to compensate for contraction

In reducing operations in India the contraction and consequent shrinkage is frequently great enough to be of importance from the point of view of Excise control Accordingly in the Reduction Tables the true amount of water to be added has been calculated by the method of separate volumes and is recorded for a large number of possible cases In blending operations, the shrinkage is usually very small, but typical example are here worked out for reference if required It is impossible to supply such results in the form of tables owing to the enormous number of cases possible

Reduction —

The rule stated in Chapter VIII gives accurately the bulk after reduction, but requires extending as follows when the water to be added is to be truly calculated

Supplementary rule for finding water to be added —Multiply the bulk after reduction and also the bulk before reduction each by the factor given in the accompanying table for its own proof strength and subtract these so as to find the separate volumes The difference is the true amount of water to be added

* For example if Q is any other quantity of spirit and X the number of separate gallons it contains then X Q 103 7 100 by direct proportion or $X = Q\frac{103\ 7}{100}$

Example —According to the example in Chapter VIII —150 gallons of 40° O P spirit become 280 gallons at 25° U P

Calculating the separate volumes (*a*) after and (*b*) before reduction

(*a*) 280 × 1 0353 (factor for 25° U P spirit) = 289 88 separate gallons
(*b*) 150 × 1 0282 (factor for 40° O P spirit) = 154 23 ,, ,,

Difference = 135 65 gallons

135 65 gallons is the correct amount of water to be added

The amount of water required by the ordinary reduction rule is 280—150=130 gallons So that 135 65—130 gives 5 6 gallons as the contraction in this instance

Blending —

Case A in Chapter VIII —The ordinary spirit calculation shows that 100 gallons at 20° U P and 450 gallons at L P when blended give 550 gallons at 3 6° U P

Calculating the separate volumes (*a*) before and (*b*) after blending

(*a*) 100 gallons at 20° U P = 100 × 1 0360 = 103 6 separate gallons
450 gallons at L P = 450 × 1 0370 = 466 66 ,, ,,

Total separate gallons before blending = 570 26 gallons

(*b*) 550 gallons at 3 6° U P = 550 × 1 03705 = 570 37 separate gallons after blending

Thus the separate volumes actually blended are less than those required by the spirit calculation by 0 11 gallon of water, or a minute shrinkage occurs which may be corrected by adding $\frac{1}{10}$th gallon of water

Case B in Chapter VIII —According to the spirit calculation 75 gallons of 40° O P spirit may be lowered to 25° O P by adding 32½th gallons of 10° U P spirit, and become 107½th gallons

Calculating the separate volumes before and after blending

(*a*) 75 × 1 028 (factor for 40° O P) =77 1 separate gallons
32½ × 1 037 (factor for 10° U P) =33 33 ,, ,,

Total 110 43 separate gallons

(*b*) 107½ × 1 0332 (factor for 25° O P)=110 70 separate gallons

The deficit is 0 27 gallon of water, or a shrinkage of ¼ per cent

Case C in Chapter VIII —According to the spirit calculation 100 gallons of 30° U P spirit may be raised to 10° O P by adding 160 gallons of 35 O P spirit and they become 260 gallons

Calculating the separate volumes

(*a*) 100 × 1 0340 (factor for 30° U P) = 103 4 separate gallons
160 × 1 0301 (factor for 35° O P) = 164 96 ,,

Total 268 36 separate gallons

(*b*) 260 × 1 0362 (factor for 10° O P) = 269 41 separate gallons

The deficit is 1 05 gallons of water or a shrinkage of 0 4 per cent

Case D in Chapter VIII —According to the spirit calculation, 66 6 gallons of 40° O P spirit and 83 4 gallons at 5° U P must be blended to obtain 150 gallons of 15° O P spirit Calculating the separate volumes —

(*a*) 66 6 × 1 0282 (factor for 40° O P) = 68 46 separate gallons
83 4 × 1 0372 (factor for 5° U P) = 86 50 ,, ,,

TOTAL 154 96 separate gallons

(*b*) 150 × 1 0354 (factor for 15° O P) = 155 30 separate gallons

The deficit is 0 34 gallons, or a shrinkage of ¼ per cent

Table of Contraction Factors.

This table shows the volume of water hidden by contraction in 100 gallons of spirit of every strength from 70° O P (170° proof) to 70° U P (30° proof), and also the factor to be used to calculate the sum of the separate volumes of alcohol and water contained in any volume of alcohol of these several strengths

Spirit strength (in terms of proof)	Spirit strength in proof spirit degrees	No of gallons of water hidden by contraction in 100 gallons	Factor for calculating the sum of the separate volumes of alcohol and water in any mixture
70° O P	170·0	0·76	1·00704
69	169·0	0·86	1·0086
68°	168·0	0·97	1·0097
67°	16[illegible]·0	1·08	1·0108
66°	166·0	1·18	1·0118
65°	165·0	1·290	1·0129
64°	164·0	1·384	1·0138
63°	163·0	1·4[illegible]0	1·0147
62°	162·0	1·550	1·0155
61°	161·0	1·630	1·0163
60°	160·0	1·700	1·0170
59	159·0	1·780	1·0178
58°	158·0	1·860	1·0186
57°	157·0	1·940	1·0194
56°	156·0	2·010	1·0201
55°	155·0	2·0[illegible]0	1·0207
54°	154·0	2·140	1·0214
53°	153·0	2·200	1·0220
52	152·0	2·260	1·0226
51°	151·0	2·310	1·0231
50°	150·0	2·370	1·0237
49°	149·0	2·420	1·0242
48°	148·0	2·470	1·0247
4[illegible]°	147·0	2·528	1·0252
46°	146·0	2·5[illegible]0	1·0257
45°	145·0	2·620	1·0262
44°	144·0	2·660	1·0266
43°	143·0	2·700	1·0270
42°	142·0	2·740	1·0274
41°	141·0	2·780	1·0278
40°	140·0	2·820	1·0282
39	139·0	2·860	1·0286
38°	138·0	2·905	1·0290
3[illegible]°	137·0	2·940	1·0294
36	136·0	2·975	1·02975
3[illegible]°	135·0	3·010	1·0301
34°	134·0	3·045	1·0304
33	133·0	3·080	1·0308
32	132·0	3·115	1·0311
31°	131·0	3·150	1·0315
30	130·0	3·185	1·0318

Spirit strength (in terms of proof)	Spirit strength in proof spirit degrees	No of gallons of water hidden by contraction in 100 gallons	Factor for calculating the sum of the separate volumes of alcohol and water in any mixture
29° O P	129 0	3 210	1 0321
28° ,,	128 0	3 240	1 0324
27° ,	127 0	3 270	1 0327
26° ,	126 0	3 295	1 0329
25° ,	125 0	3 320	1 0332
24° ,,	124 0	3 345	1 0334
23° ,,	123 0	3 370	1 0337
22° ,	122 0	3 395	1 0339
21° ,	121 0	3 420	1 0342
20° ,,	120 0	3 440	1 0344
19° ,,	119 0	3 460	1 0346
18° ,,	118 0	3 480	1 0348
17° ,,	117 0	3 500	1 0350
16° ,,	116 0	3 520	1 0352
15° ,	115 0	3 540	1 0354
14° ,	114·0	3 560	1 0356
13° ,,	113 0	3 575	1 0357
12° ,,	112 0	3 590	1 0359
11° ,,	111 0	3 605	1 0360
10°	110·0	3 620	1 0362
9° ,,	109 0	3 630	1 0363
8° ,,	108 0	3 640	1·0364
7° ,,	107 0	3 650	1 0365
6° ,	106 0	3·655	1·0365
5° ,,	105 0	3 660	1 0366
4° ,,	104 0	3 670	1 0367
3° ,,	103 0	3 675	1 0367
2° ,	102 0	3·680	1·0368
1° ,	101 0	3 690	1 0369
Proof	100 0	3 700	1 0370
1° U P	99 0	3 704	1 0370
2° ,,	98 0	3 708	1 0370
3° ,	97 0	3 712	1 0371
4° ,	96·0	3 716	1 0371
5° ,,	95 0	3 720	1 0372
6° ,,	94 0	3 716	1 03716
7° ,,	93 0	3 712	1 03712
8° ,,	92 0	3 708	1 0371
9° ,,	91 0	3 704	1·0370
10° ,,	90 0	3 700	1 0370
11° ,	89 0	3 694	1 0369
12° ,,	88 0	3 688	1·0368
13° ,,	87 0	3 682	1 0368
14° ,,	86 0	3 676	1 0367
15° ,,	85 0	3 670	1 0367
16° ,,	84·0	3 657	1 0366
17° ,	83 0	3 644	1 0364
18° ,,	82 0	3 631	1·03631
19° ,,	81 0	3 618	1·03628
20° ,,	80 0	3 605	1 0360
21° ,,	79 0	3 590	1 03590

Spirit strength (in terms of proof)	Spirit strength in proof spirit degrees	No. of gallons of water hidden by contraction in 100 gallons	Factor for calculating the sum of the separate volumes of alcohol and water in any mixture
22° U P	78·0	3·575	1·03575
23° ,,	77·0	3·560	1·03560
24° ,,	76·0	3·545	1·03545
25° ,,	75·0	3·530	1·03530
26° ,,	74·0	3·504	1·03504
27° ,,	73·0	3·478	1·03478
28° ,,	72·0	3·452	1·03452
29° ,,	71·0	3·426	1·03426
30° ,,	70·0	3·400	1·03400
31° ,,	69·0	3·370	1·03370
32° ,,	68·0	3·340	1·03340
33° ,,	67·0	3·310	1·03310
34° ,,	66·0	3·280	1·03280
35° ,,	65·0	3·250	1·03250
36° ,,	64·0	3·208	1·03208
37° ,,	63·0	3·166	1·03166
38° ,,	62·0	3·124	1·03124
39° ,,	61·0	3·082	1·03082
40° ,,	60·0	3·040	1·03040
41° ,,	59·0	2·992	1·02992
42° ,,	58·0	2·944	1·02944
43° ,,	57·0	2·896	1·02896
44° ,,	56·0	2·848	1·02848
45° ,,	55·0	2·800	1·02800
46° ,,	54·0	2·754	1·02754
47° ,,	53·0	2·708	1·02708
48° ,,	52·0	2·662	1·02662
49° ,,	51·0	2·616	1·02616
50° ,,	50·0	2·570	1·02570
51° ,,	49·0	2·510	1·02510
52° ,,	48·0	2·450	1·02450
53° ,,	47·0	2·390	1·02390
54° ,,	46·0	2·330	1·02330
55° ,,	45·0	2·270	1·02270
56° ,,	44·0	2·210	1·02210
57° ,,	43·0	2·150	1·02150
58° ,,	42·0	2·090	1·02090
59° ,,	41·0	2·030	1·02030
60° ,,	40·0	1·970	1·0197
61° ,,	39·0	1·910	1·01910
62° ,,	38·0	1·850	1·01850
63° ,,	37·0	1·790	1·01790
64° ,,	36·0	1·730	1·01730
65° ,,	35·0	1·670	1·01670
66° ,,	34·0	1·610	1·01610
67° ,,	33·0	1·550	1·01550
68° ,,	32·0	1·490	1·01490
69° ,,	31·0	1·430	1·01430
70° ,,	30·0	1·370	1·01370

APPENDIX V.

A table of the areas of circles in Imperial gallons.

Diameters in inches.	0	1	2	3	4	5	6	7	8	9
1	0028	0034	0040	0047	0055	0063	0072	0081	0091	0102
2	0113	0124	0137	0149	0163	0177	0191	0206	0222	0238
3	·0254	0272	0290	0308	0327	0346	0367	0387	0409	0430
4	0453	0476	0499	0523	0548	0573	0599	0625	0652	0680
5	0708	0736	0765	0795	0825	0856	0888	0920	0952	0986
6	1019	1053	1088	1124	1160	1196	1233	1271	1309	1348
7	1387	1427	1468	1509	1551	1593	1636	1679	1723	1767
8	1812	1858	1904	1951	1998	2046	2094	2143	2193	2243
9	2294	2345	2397	2449	2502	2556	2610	2665	2720	2776
10	2832	2889	2947	3005	3063	3122	3182	3243	3303	3365
11	3427	3490	3553	3616	3681	3746	3811	3877	3944	4011
12	4078	4147	4215	4285	4355	4425	4496	4568	4640	4713
13	4787	4860	4935	5010	5086	5162	5239	5316	5394	5472
14	5551	5631	5711	5792	5873	5955	6037	6120	6204	6288
15	6373	6458	6544	6630	6717	6805	6893	6982	7071	7161
16	7251	7342	7433	7525	7618	7711	7805	7899	7994	8090
17	8186	8282	8379	8477	8575	8674	·8774	8874	8974	9075
18	9177	9279	9382	9485	9589	9694	9799	9905	1 0011	1 0118
19	1 0225	1 0333	1 0441	1 0551	1 0660	1 0770	1 0881	1 0992	1 1104	1 1217
20	1 1330	1 1443	1 1558	1 1672	1 1788	1 1903	1 2020	1 2137	1 2254	1 2372
21	1 2491	1 2610	1 2730	1 2851	1 2972	1 3093	1 3215	1 3338	1 3461	1 3585
22	1 3709	1 3834	1 3960	1 4086	1 4212	1 4339	1 4467	1 4595	1 4724	1 4854
23	1 4984	1 5114	1 5246	1 5377	1 5510	1 5642	1 5776	1 5910	1 6044	1 6179
24	1 6315	1 6451	1 6588	1 6726	1 6863	1 7002	1 7141	1 7281	1 7421	1 7562
25	1 7703	1 7845	1 7987	1 8131	1 8274	1 8418	1 8563	1 8708	1 8854	1 9001
26	1 9148	1 9295	1 9443	1 9592	1 9741	1 9891	2 0042	2 0193	2 0344	2 0496
27	2 0649	2 0802	2 0956	2 1110	2 1265	2 1421	2 1577	2 1734	2 1891	2 2049
28	2 2207	2 2366	2 2525	2 2685	2 2846	2 3007	2 3169	2 3331	2 3494	2 3657

29	2 3821	2 3986	2 4151	2 4317	2 4483	2 4817	2 4985	2 5154	2 5323
30	2 5493	2 5663	2 5834	2 6005	2 6177	2 6523	2 6696	2 6870	2 7045
31	2 7221	2 7396	2 7573	2 7750	2 7928	2 8284	2 8464	2 8644	2 8824
32	2 9005	2 9187	2 9369	2 9551	2 9735	3 0103	3 0288	3 0473	3 0660
33	3·0846	3 1033	3 1221	3 1410	3 1599	3 1978	3 2169	3 2360	3 2552
34	3 2744	3 2937	3 3130	3 3324	3 3519	3 3910	3 4106	3 4303	3 4500
35	3 4698	3 4897	3 5096	3 5296	3 5496	3 5898	3 6100	3 6303	3 6506
36	3 6710	3 6914	3 7119	3 7324	3 7530	3 7943	3 8151	3 8359	3 8568
37	3 8777	3 8987	3 9198	3 9409	3 9620	4 0045	4 0259	4 0472	4 0687
38	4·0902	4 1117	4 1334	4 1550	4 1767	4 2204	4 2423	4 2642	4 2862
39	4 3083	4 3304	4 3526	4 3748	4 3971	4 4419	4 4643	4 4869	4 5094
40	4 5321	4 5548	4 5775	4 6003	4 6232	4 6690	4 6921	4 7152	4 7383
41	4 7615	4 7848	4 8081	4 8314	4 8549	4 9019	4 9255	4 9491	4 9728
42	4 9966	5·0204	5 0443	5 0682	5 0922	5 1404	5 1645	5 1888	5 2130
43	5 2374	5 2618	5 2862	5 3107	5 3353	5 3846	5 4093	5 4341	5 4589
44	5 4828	5 5088	5 5338	5 5588	5 5840	5 6344	5 6597	5 6850	5 7104
45	5 7359	5 7614	5 7870	5 8126	5 8383	5 8899	5 9157	5 9417	5 9676
46	5 9937	6 0198	6 0459	6 0721	6 0984	6 1510	6 1775	6 2040	6 2305
47	6·2571	6 2838	6 3105	6 3372	6 3641	6 4179	6 4449	6 4719	6 4990
48	6 5262	6 5534	6 5807	6 6080	6 6354	6 6904	6 7179	6 7455	6 7732
49	6 8010	6 8287	6 8566	6 8845	6 9124	6 9685	6 9967	7 0248	7 0531
50	7·0814	7 1097	7 1381	7 1666	7 1951	7 2524	7 2810	7 3098	7 3386
51	7 3675	7 3964	7 4254	7 4544	7 4835	7 5418	7 5711	7 6004	7 6298
52	7 6592	7 6887	7 7183	7 7479	7 7775	7 8370	7 8668	7 8967	7 9266
53	7 9566	7 9867	8·0168	8 0470	8 0772	8 1378	8 1682	8 1987	8 2292
54	8 2597	8 2903	8 3210	8 3518	8 3825	8 4443	8 4753	8 5063	8 5373
55	8 5685	8 5997	8 6309	8 6622	8 6936	8 7564	8 7880	8 8196	8 8512
56	8 8829	8 9146	8 9465	8 9783	9 0102	9 0743	9 1064	9 1385	9 1707
57	9 2030	9 2353	9 2677	9 3001	9 3326	9 3977	9 4304	9 4631	9 4959
58	9 5287	9 5616	9 5945	9 6275	9 6606	9 7269	9 7601	9 7934	9 8267
59	9 8601	9 8936	9 9271	9 9607	9 9943	10 0617	10 0955	10 1293	10 1632
60	10·1972	10·2312	10·2653	10·2994	10 3336	10 4022	10 4365	10 4709	10 5054
61	10 5399	10·5745	10 6092	10 6439	10·6786	10·7483	10 7832	10 8182	10 8533
62	10 8884	10·9235	10 9587	10·9940	11 0293	11 1001	11 1356	11 1712	11 2068
63	11 2424	11 2781	11 3139	11 3497	11 3856	11 4576	11 4936	11 5298	11 5659
64	11 6022	11 6384	11 6749	11 7112	11 7476	11 8207	11 8573	11 8940	11 9308

A table of the areas of circles in imperial gallons—contd

Diameters in inches.	0	1	2	3	4	5	6	7	8	9
65	11 9670	12·0044	12 0413	12 0783	12 1153	12 1524	12 1895	12 2267	12 2640	12 3013
66	12 3386	12 3760	12 4135	12 4511	12 4886	12 5263	12 5640	12 6017	12 6396	12 6774
67	12 7154	12 7533	12 7914	12 8295	12 8676	12 9058	12 9441	12 9824	13 0208	13 0593
68	13 0978	13 1363	13 1749	13 2136	13 2523	13 2911	13 3299	13 3688	13 4078	13 4468
69	13 4858	13 5249	13 5641	13 6033	13 6426	13 6820	13 7214	13 7608	13 8003	13 8399
70	13 8795	13 9192	13 9590	13 9988	14 0386	14 0785	14 1185	14 1585	14 1986	14 2387
71	14 2789	14 3192	14·3595	14 3999	14 4403	14 4808	14 5213	14 5619	14 6025	14 6432
72	14 6840	14 7248	14 7657	14 8066	14 8476	14 8886	14 9297	14 9709	15 0121	15 0534
73	15 0947	15 1361	15 1775	15 2190	15 2606	15 3022	15 3439	15 3856	15 4274	15 4692
74	15 5111	15 5531	15·5951	15 6371	15 6792	15 7214	15 7637	15 8059	15 8483	15 8907
75	15 9332	15 9757	16 0182	16 0609	16 1036	16 1463	16 1891	16 2320	16 2749	16 3179
76	16 3609	16 4040	16 4471	16 4903	16 5336	16 5769	16 6202	16 6637	16 7071	16 7507
77	16 7943	16 8379	16 8816	16 9254	16 9692	17 0131	17 0570	17 1010	17 1450	17 1891
78	17·2333	17 2775	17 3218	17 3661	17 4105	17 4550	17 4995	17 5440	17 5886	17 6333
79	17 6780	17 7228	17 7676	17 8125	17 8575	17 9025	17 9476	17 9927	18 0379	18 0831
80	18 1284	18 1738	18 2192	18 2646	18 3101	18 3557	18 4013	18 4470	18 4928	18 5386
81	18 5844	18 6304	18 6763	18 7224	18 7684	18 8146	18 8608	18 9070	18 9534	18 9997
82	19 0462	19 0926	19 1392	19 1858	19 2324	19 2791	19 3259	19 3727	19 4196	19 4665
83	19 5135	19 5606	19 6077	19 6548	19 7021	19 7493	19 7967	19 8441	19 8915	19 9390
84	19 9866	20·0342	20 0819	20 1296	20 1774	20 2252	20 2731	20 3211	20 3691	20 4171
85	20 4653	20·5135	20·5617	20 6100	20 6583	20 7067	20·7552	20 8037	20 8523	20 9009
86	20 9496	20 9984	21 0472	21 0961	21 1450	21 1940	21 2430	21 2921	21 3412	21 3904
87	21 4397	21 4890	21 5384	21 5878	21 6373	21 6868	21 7364	21 7861	21 8358	21 8856
88	21 9354	21 9853	22 0352	22 0852	22 1352	22 1854	22 2355	22 2857	22 3360	22 3863
89	22 4367	22 4872	22 5377	22 5883	22 6389	22 6895	22 7403	22 7911	22 8419	22 8928
90	22 9438	22 9948	23 0459	23 0970	23 1482	23 1994	23 2507	23 3021	23 3535	23 4049
91	23 4565	23 5080	23 5597	23 6114	23 6631	23 7149	23 7668	23 8187	23 8707	23 9227
92	23 9748	24 0270	21 0792	24 1314	24 1838	24 2361	24·2886	24 3411	24 3936	24 4462

93	24 4989	24 5516	24 6043	[illegible]	24 7100	24 7630	24 8160	24 8690	[illegible]	24 9753
94	25 0285	25 0818	25 1352	[illegible]	25 2420	25 2955	25 3491	25 4027	[illegible]	25 5101
95	25 5639	25 6177	25 6717	[illegible]	25 7796	25 8337	25 8878	25 9420	[illegible]	26 0506
96	26 1049	26 1593	26 2138	[illegible]	26 3229	26 3776	26 4323	26 4870	[illegible]	26 5967
97	26 6516	26 7066	26 7616	[illegible]	26 8719	26 9271	26 9823	27 0377	[illegible]	27 1485
98	27 2040	27 2595	27 3151	[illegible]	27 4265	27 4823	27 5381	27 5940	[illegible]	27 7059
99	27 7620	27 8181	27 8743	[illegible]	27 9868	28 0431	28 0995	28 1560	[illegible]	28 2690
100	28 3257	28 3823	28 4391	[illegible]	28 5527	28 6096	28 6666	28 7236	[illegible]	28 8378
101	28 8950	28 9522	29 0096	[illegible]	29 1243	29 1818	29 2393	29 2969	[illegible]	29 4123
102	29 4700	29 5278	29 5857	[illegible]	29 7016	29 7596	29 8177	29 8759	[illegible]	29 9924
103	30 0507	30 1091	30 1675	[illegible]	30 2845	30 3432	30 4018	30 4605	[illegible]	30 5781
104	30 6370	30 6960	30 7550	[illegible]	30 8732	30 9323	30 9916	31 0508	[illegible]	31 1696
105	31 2240	31 2886	31 3481	[illegible]	31 4674	31 5272	31 5870	31 6468	[illegible]	31 7667
106	31 8267	31 8863	31 9460	[illegible]	32 0674	32 1277	32 1880	32 2485	[illegible]	32 3695
107	32 4301	32 4907	32 5514	[illegible]	32 6730	32 7338	32 7948	32 8558	[illegible]	32 9779
108	33 0391	33 1003	33 1615	[illegible]	33 2842	33 3457	33 4072	33 4687	[illegible]	33 5920
109	33 6537	33 7153	33 7773	[illegible]	33 9012	33 9632	34 0252	34 0874	[illegible]	34 2118
110	34 2741	34 3761	34 3988	[illegible]	34 5238	34 5863	34 6490	34 7117	[illegible]	34 8372
111	34 9001	34 9636	35 0259	[illegible]	35 1520	35 2152	35 2784	35 3416	[illegible]	35 4683
112	35 5317	35 5952	35 6587	[illegible]	35 7860	35 8497	35 9134	35 9772	[illegible]	36 1051
113	36 1700	36 2331	36 2972	[illegible]	36 4256	36 4898	36 5542	36 6185	[illegible]	36 7475
114	36 8120	36 8769	36 9413	[illegible]	37 0708	37 1357	37 2006	37 2655	[illegible]	37 3956
115	37 4607	37 5259	37 5911	[illegible]	37 7217	37 7871	37 8526	37 9181	[illegible]	38 0493
116	38 1150	38 1808	38 2166	[illegible]	38 3783	38 4413	38 5103	38 5764	[illegible]	38 7088
117	38 7750	38 8413	38 9077	[illegible]	39 0406	39 1071	39 1737	39 2404	[illegible]	39 3738
118	39 4407	39 5077	39 5745	[illegible]	39 7095	39 7756	39 8428	39 9100	[illegible]	40 0446
119	40 1120	40 1794	40 2469	[illegible]	40 3821	40 4498	40 5175	40 5853	[illegible]	40 7210
120	40 7800	40 8570	40 9250	[illegible]	41 0613	41 1296	41 1979	41 2662	[illegible]	41 4031
121	41 4710	41 5102	41 6088	[illegible]	41 7463	41 8151	41 8839	41 9528	[illegible]	42 0908
122	42 1709	42 2291	42 2983	[illegible]	42 4368	42 5062	42 5756	42 6451	[illegible]	42 7843
123	42 8739	42 9236	42 9934	[illegible]	43 1331	43 2030	43 2730	43 3431	[illegible]	43 4833
124	43 5530	43 6238	43 6942	[illegible]	43 8350	43 9055	43 9761	44 0467	[illegible]	44 1881
125	44 2589	44 3297	44 4006	[illegible]	44 5426	44 6130	44 6848	44 7560	[illegible]	44 8985
126	44 9643	45 0112	45 1127	[illegible]	45 2579	45 3275	45 3991	45 4709	[illegible]	45 6146
127	45 6805	45 7793	45 8305	[illegible]	45 9747	46 0169	46 1102	46 1915	[illegible]	46 3363
128	46 4044	46 1913	46 5530	[illegible]	46 6093	46 7721	46 8449	46 9178	[illegible]	47 0637

A table of the areas of circles in imperial gallons—contd

Diameters in inches.	0	1	2	3	4	5	6	7	8	9
129	47 1368	[illegible]	47 2830	47 3563	47 4295	47 5029	47 5763	47 6497	47 7232	47 7968
130	47 8704	[illegible]	48 0178	48 0916	48 1654	48 2393	48 3133	48 3873	48 4614	48 5355
131	48 6097	[illegible]	48 7582	48 8326	48 9070	48 9815	49 0560	49 1306	49 2052	49 2799
132	49 3547	[illegible]	49 5043	49 5793	49 6542	49 7293	49 8044	49 8795	49 9547	50 0300
133	50·1053	[illegible]	50 2561	50 3316	50 4071	50 4827	50 5584	50 6341	50 7099	50 7857
134	50·8616	[illegible]	51 0135	51 0896	51 1657	51 2419	51 3181	51 3944	51 4707	51 5471
135	51 6235	[illegible]	51 7766	51 8532	51 9299	52 0067	52 0834	52 1603	52 2372	52 3142
136	52 3912	[illegible]	52 5454	52 6226	52 6998	52 7771	52 8545	52 9319	53 0094	53·0869
137	53 1645	[illegible]	53 3198	53 3976	53 4754	53 5532	53 6312	53 7091	53 7872	53 8653
138	53 9434	[illegible]	54 0999	54 1782	54 2566	54 3350	54 4135	54 4921	54 5707	54 6493
139	54 7280	[illegible]	54 8856	54 9645	55 0435	55 1225	55 2015	55 2807	55 3598	55 4390
140	55 5183	[illegible]	55 6771	55 7565	55 8360	55 9156	55 9952	56 0749	56 1546	56 2344
141	56 3143	[illegible]	56 4742	56 5542	56 6343	56 7144	56 7946	56 8748	56 9551	57 0355
142	57 1159	[illegible]	57 2769	57 3575	57 4381	57 5188	57 5996	57·6804	57 7613	57 8422
143	57 9232	[illegible]	58 0853	58 1665	58 2477	58 3290	58 4103	58 4917	58 5731	58 6546
144	58 7361	[illegible]	58 8994	58 9811	59 0629	59 1447	59 2266	59 3086	59 3906	59 4726
145	59 5547	[illegible]	59 7191	59 8014	59 8838	59 9662	60 0486	60 1311	60 2137	60 2963
146	60 3790	[illegible]	60 5446	60 6274	60 7103	60 7933	60 8763	60 9594	61 0425	61 1257
147	61 2090	[illegible]	61 3756	61 4591	61 5425	61 6261	61 7097	61 7933	61 8770	61 9608
148	62 0446	[illegible]	62 2124	62 2964	62 3804	62 4645	62 5487	62 6329	62 7171	62 8015
149	62 8858	[illegible]	63 0548	63 1393	63 2239	63 3086	63 3933	63 4781	63 5629	63 6478
150	63 7328	[illegible]	63 9029	63 9880	64 0731	64 1584	64 2437	64 3290	64 4144	64 4999
151	64 5854	[illegible]	64 7566	64 8423	64 9280	65 0138	65 0997	65 1856	65 2716	65 3576
152	65 4437	[illegible]	65·6160	65 7022	65 7886	65 8749	65 9613	66 0478	66 1344	66 2209
153	66 3076	[illegible]	66 4811	66 5679	66 6548	66 7417	66 8287	66 9157	67 0028	67 0900
154	67 1772	[illegible]	67 3518	67 4392	67 5266	67 6141	67 7017	67 7893	67 8770	67 9647
155	68 0525	[illegible]	68 2282	68 3161	68 4041	68 4922	68 5803	68 6685	68 7567	68 8450
156	68 9334	[illegible]	69 1103	69 1988	69 2873	69 3760	69 4647	69 5534	69 6422	69 7311
157	69 8200	[illegible]	69 9980	70 0871	70 1762	70 2654	70 3547	70 4440	70 5333	70 6228

158	70·7122	70·8018		70 9810		71 1605	71 2503	71 3402	71 4301	71 5201
159	71 6102	71 7003		71 8806		72 0613	72 1516	72 2421	72 3326	72 4231
160	72 5128	72 6044		72 7859		72 9677	73 0586	73 1496	73 2407	73 3318
161	73 4230	73 5142		73 6969		73 8798	73 9713	74 0629	74 1545	74 2462
162	74 3379	74 4297		74 6135		74 7975	74 8896	74 9817	75 0739	75 1662
163	75·2585	75·3509		75·5358		75 7209	75 8136	75 9063	75 9991	76 0919
164	76·1848	76·2777		76 4637		76 6500	76 7432	76 8365	76 9298	77 0232
165	77 1167	77 2102		77 3974		77 5848	77 6786	77 7724	77 8663	77 9603
166	78 0543	78 1483		78 3366		78 5252	78 6195	78 7139	78 8084	78 9029
167	78 9975	79 0921		79 2816		79 4713	79 5662	79 6612	79 7562	79 8513
168	79 9464	80 0416		80 2322		80 4230	80 5185	80 6140	80 7096	80 8053
169	80·9010	80·9968		81 1885		81 3804	81 4765	81 5726	81 6687	81 7650
170	81 8612	81 9576		82 1504		82 3435	82 4401	82 5368	82 6335	82 7303
171	82 8271	82 9240		83 1180		83 3122	83 4094	83 5067	83 6039	83 7013
172	83 7987	83 8962		84 0913		84 2866	84 3844	84 4822	84 5801	84 6780
173	84 7760	84 8740		85 0702		85 2667	85 3650	85 4634	85 5618	85 6603
174	85·7589	85 8575		86 0548		86 2524	86 3513	86 4503	86 5493	86 6483
175	86 7474	86 8466		87 0451		87 2438	87 3433	87 4428	87 5424	87 6420
176	87 7417	87 8414		88 0410		88 2409	88 3409	88 4410	88 5411	88 6413
177	88 7416	88 8419		89·0426		89 2436	89 3442	89 4449	89 5455	89 6463
178	89 7471	89 8480		90·0499		90 2520	90 3532	90 4544	90 5556	90 6570
179	90·7583	90·8598		91 0628		91 2661	91 3678	91 4696	91 5714	91 6733
180	91 7752	91 8772		92 0814		92 2858	92 3881	92 4904	92 5928	92 6953
181	92 7978	92 9004		93 1057		93 3112	93 4140	93 5170	93 6199	93 7229
182	93 8260	93 9292		94 1356		94 3423	94 4457	94 5491	94 6527	94 7563
183	94 8599	94 9636		95 1712		95 3790	95 4830	95 5870	95 6911	95 7952
184	95 8995	96 0037		96 2124		96 4214	96 5259	96 6305	96 7352	96 8399
185	96 9447	97·0495		97 2593		97 4694	97 5745	97 6797	97 7849	97 8902
186	97 9956	98 1010		98 3119		98 5231	98 6288	98 7345	98 8403	98 9462
187	99 0521	99 1581		99 3702		99 5825	99 6888	99 7951	99 9014	100 0078
188	100 1143	100·2209		100 4341		100·6476	100 7544	100 8612	100 9682	101 0752
189	101 1822	101 2893		101 5037		101 7183	101 8256	101 9331	102 0406	102 1481
190	102 2557	102 3634		102 5789		102 7946	102 9026	103 0106	103 1187	103 2268
191	103 3350	103 4432		103 6598		103 8767	103 9852	104 0938	104 2024	104 3111
192	104 4198	104 5286		104 7464		104 9644	105 0735	105 1826	105 2918	105 4011
193	105 5104	105 6197		105 8380		106 0578	106 1674	106 2771	106 3869	106 4967

A table of the areas of circles in imperial gallons—contd

Dia meters in inches.	0	1	2	3	4	5	6	7	8	9
194	106 6066	106 7165	106 8265	106 9365	107 0466	107 1568	107 2670	107 3773	107 4876	107 5980
195	107 7084	107 8189	107 9295	108 0401	108 1508	108 2615	108 3723	108 4831	108 5940	108 7050
196	108 8160	108 9270	109 0382	109 1493	109 2606	109 3719	109 4832	109 5946	109 7061	109 8176
197	109 9292	110 0408	110 1525	110 2642	110 3760	110 4879	110 5998	110 7118	110 8238	110 9359
198	111 0480	111 1602	111 2725	111 3848	111 4972	111 6096	111 7221	111 8346	111 9472	112 0599
199	112 1726	112 2853	112 3982	112 5110	112 6240	112 7370	112 8500	112 9631	113 0763	113 1895
200	113 3028	113 4161	113 5295	113 6429	113 7564	113 8700	113 9836	114 0973	114 2110	114 3248
201	114 4386	114 5525	114 6665	114 7805	114 8946	115 0087	115 1229	115 2371	115 3514	115 4658
202	115 5802	115 6046	115 8091	115 9237	116 0384	116 1530	116 2678	116 3826	116 4975	116 6124
203	116 7273	116 8424	116 9575	117 0726	117 1878	117 3031	117 4184	117 5338	117 6492	117 7647
204	117 8802	117 9958	118 1115	118 2272	118 3429	118 4588	118 5746	118 6906	118 8066	118 9226
205	119 0387	119·1549	119 2711	119 3874	119 5037	119 6201	119·7366	119 8531	119 9696	120 0862
206	120 2029	120·3196	120 4364	120 5533	120 6702	120 7871	120 9041	121 0212	121 1383	121 2555
207	121 3728	121 4901	121 6074	121 7248	121 8423	121 9598	122 0774	122 1950	122 3127	122 4305
208	122 5483	122 6661	122 7841	122 9020	123 0201	123 1382	123 2563	123 3745	123 4928	123 6111
209	123 7295	123 8479	123 9664	124 0840	124 2035	124 3222	124 4409	124 5597	124 6785	124 7974
210	124 9163	125·0353	125 1544	125 2735	125 3926	125 5119	125 6311	125 7505	125 8699	125 9893
211	126 1089	126 2284	126 3480	126·4677	126 5874	126 7072	126 8270	126 9470	127 0669	127 1869
212	127 3070	127 4271	127 5473	127 6670	127 7879	127 9082	128 0286	128 1491	128 2696	128 3902
213	128 5108	128 6315	128 7523	128 8731	128 9940	129 1149	129 2359	129 3569	129 4780	129 5991
214	129 7204	129 8416	129 9629	130 0843	130 2057	130 3272	130 4488	130 5704	130 6920	130 8138
215	130 9355	131·0774	131 1792	131 3012	131 4232	131 5452	131 6673	131 7895	131 9117	132 0340
216	132 1564	132 2789	132 4012	132 5237	132 6463	132 7689	132 8916	133 0143	133 1371	133 2600
217	133 3829	133 5078	133 6288	133 7519	133 8751	133 9982	134 1215	134 2448	134 3681	134 4916
218	134 6150	134 7386	134 8621	134 9858	135 1095	135 2332	135 3571	135 4809	135 6048	135 7288
219	135 8529	135 9770	136·1011	136 2253	136 3496	136 4739	136 5983	136 7227	136 8472	136 9718
220	137 0964	137 2210	137 3457	137 4705	137 5953	137 7202	137 8452	137 9702	138 0052	138 2204
221	138 3155	138 4708	138 5960	138 7214	138 8468	138 9722	139 0077	139 2233	139 3489	139 4740

222	139 6001		139 8520	139 9779	140 1039	140 2299	140 3560	140 4821	140 6083	140 7345
223	140·8609		141 1136	141 2401	141 3666	141·4932	141 6199	141 7466	141 8733	142 0001
224	142 1270		142 3809	142 5080	142 6351	142·7622	142 8894	143 0167	143 1440	143 2714
225	143 3988		143 6539	143 7815	143 9091	144 0369	144 1646	144 2925	144 4204	144 5483
226	144 6763		144 9325	145 0607	145 1889	145 3172	145 4455	145 5739	145 7024	145 8309
227	145 9595		146 2168	146 3455	146 4743	146 6032	146 7321	146 8611	146 9901	147 1192
228	147 2483		147 5067	147 6360	147 7654	147 8948	148 0243	148 1538	148 2834	148 4131
229	148 5428		148 8024	148 9322	149 0622	149 1921	149 3222	149 4523	149 5824	149 7127
230	149 8121		150·1036	150·2341	150 3646	150 4951	150 6257	150 7564	150 8871	151 0179
231	151 1487		151 4106	151 5416	151 6727	151 8038	151 9350	152 0662	152 1975	152 3288
232	152 4602		152 7232	152 8548	152 9864	153 1181	153 2498	153 3816	153 5135	153 6454
233	153 7774		154 0415	154 1736	154 3058	154 4381	154 5704	154 7027	154 8352	154 9676
234	155·1002		155 3654	155 4981	155 6309	155 7637	155 8966	156 0295	156 1625	156 2956
235	156 4287		156 6950	156 8283	156 9616	157 0950	157 2285	157 3620	157 4955	157 6291
236	157 7628		158 0303	158 1641	158 2980	158 4320	158 5660	158 7001	158 8342	158 9684
237	159 1026		159 3712	159 5057	159 6401	159 7746	159 9092	160 0438	160 1785	160 3133
238	160 4481		160 7178	160 8528	160 9879	161 1229	161 2581	161 3933	161 5285	161 6638
239	161 7992		162 0701	162 2057	162 3413	162 4769	162 6126	162 7484	162 8842	163 0201
240	163 1560		163 4281	163 5642	163 7003	163 8365	163 9728	164 1091	164 2455	164 3820
241	164 5185		164 7917	164 9283	165 0651	165 2018	165 3387	165 4756	165 6125	165 7495
242	165 8860		166 1609	166 2982	166 4354	166 5728	166 7102	166 8477	166 9852	167 1228
243	167 2604		167 5358	167 6737	167 8115	167 9494	168 0874	168 2254	168 3635	168 5017
244	168 6399		168 9164	169 0548	169 1932	169 3317	169 4703	169 6089	169 7475	169 8862
245	170 0250		170·3027	170 4416	170 5806	170 7197	170 8588	170 9980	171 1372	171 2765
246	171 4158		171 6946	171 8341	171 9737	172 1133	172 2530	172 3927	172 5325	172 6723
247	172 8122		173 0922	173 2323	173 3724	173 5126	173 6528	173 7931	173 9335	174 0739
248	174 2144		174 4955	174 6361	174 7768	174 9176	175 0584	175 1992	175 3401	175 4811
249	175 6222		175 9044	176 0456	176 1869	176 3282	176 4695	176 6110	176 7525	176 8940
250	177 0356		177 3190	177 4607	177 6026	177 7445	177 8864	178 0284	178 1704	178 3126
251	178 4547		178 7392	178 8816	179 0240	179 1664	179 3089	179 4515	179 5941	179 7368
252	179 8795		180·1651	180 3080	180 4510	180·5940	180 7371	180 8802	181 0234	181 1667
253	181 3100		181 5967	181 7402	181 8837	182 0273	182 1709	182 3146	182 4584	182 6022
254	182 7461		183 0340	183 1780	183 3221	183 4663	183 6105	183 7547	183 8990	184 0434
255	184 1878		184 4769	184 6215	184 7661	184 9109	185 0556	185 2005	185 3454	185 4903
256	185 6354		185 9255	186 0706	186 2159	186 3611	186 5065	186 6519	186 7973	186 9428
257	187·0884		187 3797	187 5254	187 6712	187 8171	187 9630	188 1089	188 2550	188·4010

A table of the areas of circles in imperial gallons—contd.

Diameters in inches.	0	1	2	3	4	5	6	7	8	9
258	188 5472	4	188 8396	188 9859	189 1323	189 2787	189 4252	189 5717	189 7183	189 8649
259	190 0116	4	190 3052	190 4521	190 5990	190 7460	190 8930	191 0401	191 1872	191 3345
260	191 4817	0	191 7784	191 9239	192 0713	192 2189	192 3665	192 5142	192 6619	192 8097
261	192 9575	4	193 2533	193 4013	193 5494	193 6975	193 8457	193 9939	194 1422	194 2905
262	194 4389	4	194 7359	194 8845	195 0331	195 1818	195 3305	195 4793	195 6281	195 7771
263	195 9260	0	196 2241	196 3733	196 5224	196 6717	196 8210	196 9704	197 1198	197 2693
264	197 4188	4	197 7180	197 8677	198 0175	198 1673	198 3172	198 4671	198 6171	198 7671
265	198 9172	4	199 2176	199 3678	199 5182	199 6686	199 8190	199 9695	200 1200	200 2706
266	200 4213	0	200 7228	200 8736	201 0245	201 1755	201 3265	201 4775	201 6287	201 7798
267	201 9311	4	202 2337	202 3851	202 5366	202 6881	202 8396	202 9913	203 1430	203 2947
268	203 4465	4	203 7503	203 9022	204 0543	204 2063	204 3585	204 5107	204 6629	204 8152
269	204 9676	0	205 2725	205 4250	205 5776	205 7303	205 8830	206 0357	206 1885	206 3414
270	206 4943	3	206 8004	206 9535	207 1066	207 2598	207 4131	207 5664	207 7198	207 8733
271	208 0268	3	208 3339	208 4876	208 6413	208 7951	208 9489	209 1028	209 2568	209 4108
272	209 5648	0	209 8731	210 0274	210 1817	210 3360	210 4904	210 6449	210 7994	210 9540
273	211 1086	3	211 4180	211 5728	211 7277	211 8826	212 0376	212 1926	212 3477	212 5028
274	212 6580	3	212 9686	213 1239	213 2794	213 4348	213 5904	213 7460	213 9016	214 0573
275	214 2131	9	214 5248	214 6807	214 8367	214 9928	215 1489	215 3050	215 4612	215 6175
276	215 7738	2	216 0867	216 2432	216 3997	216 5563	216 7130	216 8697	217 0265	217 1834
277	217 3403	2	217 6542	217 8113	217 9684	218 1256	218 2828	218 4401	218 5975	218 7549
278	218 9123	9	219 2274	219 3851	219 5427	219 7005	219 8583	220 0162	220 1741	220 3320
279	220 4901	2	220 8063	220 9645	221 1228	221 2811	221 4394	221 5978	221 7563	221 9149
280	222 0735	1	222 3908	222 5496	222 7084	222 8673	223 0262	223 1852	223 3443	223 5034
281	223 6626	8	223 9810	224 1404	224 2998	224 4592	224 6187	224 7783	224 9379	225 0976
282	225 2573	1	225 5769	225 7368	225 8968	226 0568	226 2169	226 3770	226 5372	226 6974
283	226 8577	0	227 1785	227 3389	227 4994	227 6600	227 8207	227 9814	228 1421	228 3029
284	228 4638	7	228 7857	228 9467	229 1078	229 2689	229 4301	229 5914	229 7527	229 9141
285	230 0755	0	230 3985	230 5601	230 7218	230 8835	231 0453	231 2071	231 3690	231 5309

286	231 6029	231 8549	232 6660	34
287	233 3160	233 4786	234 2925	16
288	234 9447	235 1079	235 9246	4
289	236 5791	236 7428	237 5624	19
290	238 2191	238 3834	239 2059	00
291	239 8649	240 0297	240 8550	09
292	241 5162	241 6817	242 5098	43
293	243 1733	243 3393	244 1702	05
294	244 8360	245 0026	245 8364	73
295	246 5044	246 6716	247 5082	08
296	248 1785	248 3462	249 1856	09
297	249 8582	250·0264	250·8687	8
298	251 5435	251·7124	252 5575	12
299	253 2340	253 4040	254 2519	4
300	254 9313	255 1013	255 9520	12
301	256 6337	256 8042	257 6578	07
302	258 3417	258 5129	259 3693	18
303	260 0554	260 2271	261 0864	76
304	261 7748	261 9470	262 8091	71
305	263 4998	263 6726	264 5376	72
306	265 2305	265 4039	266 2717	30
307	266 9669	267 1409	268 0114	15
308	268 7089	268 8834	269 7569	6
309	270·4566	270 6317	271 5080	14
310	272 2100	272 3856	273 2647	28
311	273 9690	274 1452	275 0271	10
312	275·7337	275 9105	276 7952	18
313	277 5041	277 6814	278 5690	22
314	279 2801	279 4580	280 3484	13
315	281 0618	281 2102	282 1335	01
316	282 8491	283·0282	283 9242	26
317	284 6421	284 8217	285 7207	07
318	286 4408	286 6210	287 5227	15
319	288 2452	288 4259	289 3305	39
320	290 0552	290 2365	291·1439	00
321	291 8709	292 0527	292 9630	08

A table of the areas of circles in imperial gallons—contd

Diameters in inches.	0	1	2	3	4	5	6	7	8	9
322	293 0922	293 8746	71		3	294 6050	294 7877	294 9705	295 1533	295 3362
323	295 5192	295 7022	53		6	296 4348	296 6181	296 8015	296 9849	297 1684
324	297 3519	297 5355	91		5	298 2703	298 4542	298 6381	298 8221	299 0061
325	299 1902	299 3744	86		1	300 1115	300 2959	300 4804	300 6650	300 8496
326	301 0342	301 2189	37		4	301 9583	302 1433	302 3284	302 5135	302 6987
327	302 8839	303 0692	45		3	303 8108	303 9964	304 1820	304 3677	304 5534
328	304 7392	304 9251	10		9	305 6690	305 8551	306 0413	306 2276	306 4139
329	306 6002	306 7866	31		2	307 5328	307 7195	307 9063	308 0931	308 2800
330	308 4669	308 6539	09		1	309 4023	309 5896	309 7769	309 9643	310 1517
331	310 3392	310 5268	44		7	311 2775	311 4653	311 6532	311 8412	312 0292
332	312 2172	312 4053	35		0	312 1583	313 3467	313 5352	313 7237	313 9122
333	314 1009	314 2895	83		9	314 0448	315 2338	315 4228	315 6119	315 8010
334	315 9902	316 1794	87		5	316 9370	317 1265	317 3161	317 5057	317 6954
335	317 8852	318 0750	49		8	319 8348	319 0249	319 2150	319 4052	319 5955
336	319 7858	319 9762	66		7	320 7383	320 9289	321 1197	321 3104	321 5013
337	321 6922	321 8831	41		3	322 6474	322 8387	323 0299	323 2213	323 4127
338	323 6041	323 7956	72		5	324 5623	324 7540	324 9459	325 1378	325 3298
339	325 5218	325 7139	60		4	326 4827	326 6751	326 8675	327 0600	327 2525
340	327 4451	327 6377	04		0	328 4089	328 6018	328 7948	328 9878	329 1809
341	329 3741	329 5673	06		3	330 3407	330 5342	330 7277	330 9213	331 1150
342	331 3087	331 5025	63		2	332 2782	332 4722	332 6664	332 8605	333 0548
343	333 2490	333 4434	78		8	334 2213	334 4159	334 6106	334 8054	335 0002
344	335 1950	335 3899	49		0	335 1701	336 3653	336 5606	336 7559	336 9512
345	337 1467	337 3421	77		9	337 1246	338 3204	338 5162	338 7121	338 9080
346	339 1040	339 3000	61		5	339 0847	340 2811	340 4774	340 6739	340 8704
347	341 0669	341 2635	02		7	341 0505	342 2474	342 4444	342 6414	342 8385
348	343 0356	343 2327	00		6	343 0220	344 2195	344 4170	344 6146	344 8122
349	345 0099	345 2070	54		2	345 9001	346 1972	346 3953	346 5934	346 7915

350	346 9898	347 3865	347 7834	348 1805	2	348 5779	348 7767
351	348 9755	349 3733	349 7713	350 1696	8	350 5681	350 7674
352	350·9668	351 3657	351 7649	352 1643	0	352 5639	352 7638
353	352 9637	353 3638	353 7641	354 1646	0	354 5654	354 7658
354	354 9661	355 3676	355 7690	356 1707	6	356 5725	356 7736
355	356 9747	357 3770	357 7796	358 1823	8	358 5854	358 7870
356	358 9886	359 3921	359 7958	360 1997	8	360 6039	360 8060
357	361·0082	361 4128	361 8177	362 2227	3	362 6280	362 8307
358	363·0335	363 4393	363 8452	364 2514	6	364 6578	364 8611
359	365 0645	365 4713	365 8784	366 2858	5	366 6933	366·8972
360	367 1011	367 5091	367 9173	368 3258	1	368 7345	368 9389
361	369 1434	369 5525	369 9619	370 3715	3	370 7813	370 9863
362	371 1913	371 6016	372 0121	372 4228	3	372 8338	373 0393
363	373 2449	373 6563	374·0680	374 4798	8	374 8919	375 0980
364	375 3042	375 7168	376 1295	376 5425	1	376 9557	377 1624
365	377 3692	377 7828	378 1967	378 6108	0	379 0252	379 2325
366	379 4398	379 8546	380 2696	380 6849	6	381 1003	381 3082
367	381 5160	381 9320	382 3481	382 7645	8	383 1811	383 3895
368	383 5980	384 0151	384 4323	384 8499	7	385 2676	385 4766
369	385 6856	386·1038	386 5222	386 9409	3	387 3597	387 5693
370	387 7789	388 1982	388 6178	389 0375	5	389 4576	389 6676
371	389 8778	390·2983	390 7190	391 1399	4	391 5610	391·7717
372	391 9824	392 4040	392 8258	393 2479	0	393 6702	393 8814
373	394 0927	394 5154	394 9383	395 3615	2	395 7849	395 9967
374	396 2086	396 6325	397 0565	397 4809	1	397 9054	398 1178
375	398 3302	398 7552	399 1804	399 6059	7	400 0315	400 2445
376	400·4574	400·8836	401 3099	401 7365	9	402 1633	402 3768
377	402 5904	403 0176	403 4451	403 8728	8	404 3008	404 5148
378	404 7290	405 1574	405 5860	406 0148	3	406 4439	406 6585
379	406 8732	407 3027	407 7325	408 1625	6	408 5927	408 8079
380	409 0231	409 4538	409 8847	410 3158	5	410 7472	410 9629
381	411 1787	411·6105	412 0425	412 4748	0	412 9073	413 1236
382	413 3400	413 7729	414 2061	414 6394	2	415 0731	415 2899
383	415 5069	415 9410	416 3752	416 8098	1	417 2445	417 4620
384	417 6795	418 1147	418 5501	418 9857	6	419 4216	419 6396
385	419 8577	420 2940	420 7306	421 1674	9	421·6014	421 8230

A table of the areas of circles in imperial gallons—concld

Diameters in inches	0	1	2	3	4	5	6	7	8	9
386	422 0410	422 2603	422 4791	422 6979	422 9168	423 1357	423 3547	423 5737	423 7928	424 0120
387	424 2312	424 4505	424 6698	424 8892	425 1086	425 3281	425 5477	425 7673	425 9869	426 2067
388	426 4264	426 6463	426 8662	427 0861	427 3061	427 5262	427 7463	427 9665	428 1867	428 4070
389	428 6274	428 8478	429 0682	429 2887	429 5093	429 7299	429 9506	430 1714	430 3922	430 6130
390	430 8339	431 0549	431 2759	431 4970	431 7181	431 9393	432 1606	432 3819	432 6033	432 8247
391	433·0462	433 2677	433 4893	433 7109	433 9326	434 1544	434 3762	434 5981	434 8200	435 0420
392	435 2641	435 486	435 7083	435 9305	436 1528	436 3751	436 5975	436 8200	437 0425	437 2650
393	437 4876	437 7103	437 9330	438 1558	438 3787	438 6015	438 8245	439 0475	439 2706	439 4937
394	439 7169	439 9401	440·1634	440 3867	440 6101	440 8336	441 0571	441 2807	441 5043	441 7280
395	441 9518	442 1756	442 3994	442 6233	442 8473	443 0713	443 2954	443 5196	443 7438	443 9680
396	444 1923	444 4167	444 6411	444 8656	445 0901	445 3147	445 5394	445 7641	445 9889	446 2137
397	446 4386	446 6635	446 8885	447 1135	447 3386	447 5638	447 7890	448 0143	448 2396	448 4650
398	448 6905	448 9160	449 1415	449 3671	449 5928	449 8185	450 0443	450 2701	450 4960	450 7220
399	450 9480	451 1741	451 4002	451 6264	451 8526	452 0789	452 3053	452 5317	452 7581	452 9847
400	453 2112									

	Factors for		Divisors for		Gauge points for	
	Squares	Circles	Squares	Circles	Squares	Circles
Gallon .	0036065	00283257	277 274	353 0362	16 65	18 789
Bushel .	00045081	000354071	2218 192	2824 2897	47 097	53 144

Examples for finding the area of any Circle within the limits of the table in Imperial Gallons

First—Suppose it is required to find the area of a circle, the diameter of which is 69 inches, find out 69 in the left-hand column, and directly against it, in the next column under 0, is the area, 13 4858 gallons

Second—Suppose it is required to find the area of a circle, the diameter of which is 377 8 inches, find out 377 in the left-hand column, and at the angle of meeting under 8 at the head of the table is the area 401 3008 gallons.

APPENDIX

Ullage table

Quotient	Equivalent	Quotient	Equivalent	Quotient	Equivalent	Quotient
002	0002	106	0409	21	1325	314
004	0004	108	0423	212	1345	316
006	0006	11	0436	214	1365	318
008	0008	112	045	216	1385	32
01	00	114	0464	218	1405	322
012	00146	116	0478	22	1425	324
014	00192	118	0492	222	1448	326
016	00238	12	0507	224	1471	328
018	00284	122	0522	226	1494	33
02	0033	124	0538	228	1517	332
022	00374	126	0553	23	154	334
024	00418	128	0569	232	1562	336
026	0 462	3	0585	234	1584	338
028	00506	132	0601	236	1606	34
03	0055	134	0617	238	1628	342
032	0059	136	0633	24	165	344
034	0063	138	0649	242	1672	346
036	0068	14	0665	244	1694	348
038	0072	142	0682	246	1716	35
04	00 7	144	0699	2 8	1738	352
042	0083	146	0716	25	176	354
044	0089	148	·0733	252	1782	356
046	0095	15	0 75	254	1804	358
048	0102	152	0768	256	1826	36
·05	011	154	0 86	258	1848	362
052	0118	156	0804	26	187	364
054	0126	158	0822	262	1891	366
056	0134	16	084	264	1912	368
058	0142	162	0858	266	1933	37
06	0152	164	0876	268	1954	372
062	0162	166	0894	27	1975	374
064	0172	168	0912	272	1996	376
066	0182	17	093	274	2017	378
068	0192	172	0949	276	2038	38
07	0202	174	0968	278	2059	382
072	0214	176	0987	·28	208	384
074	0225	178	1006	282	2102	386
076	0235	18	1025	284	2124	388
078	0245	182	1045	286	2146	39
08	0255	184	1065	288	2168	392
082	0266	186	1085	29	210	394
084	0277	188	1105	292	2214	396
086	0288	19	1125	294	2238	398
088	0299	192	1145	296	2262	4
·09	031	194	1165	298	2286	402
092	0322	196	1185	3	231	404
·094	0332	198	1205	302	2336	406
096	0345	2	1225	304	2362	408
098	·0358	202	1245	306	2388	41
1	037	204	1265	308	2414	412
102	0383	206	1285	31	244	414
104	0396	208	1305	312	2461	416

VI.

for lying casks.

Equivalent	Quotient	Equivalent	Quotient	Equivalent	Quotient	Equivalent
2488	418	3832	522	5316	626	6752
2512	42	386	524	5342	628	67
2536	422	3888	526	5368	63	68
256	424	3916	528	5394	632	6826
2582	426	3944	53	542	634	6852
2604	428	3972	532	5448	636	6878
2626	43	4	534	5476	638	6904
2648	432	4028	536	5504	64	693
267	434	4056	538	5532	642	6956
2698	436	4084	54	556	644	6982
2726	438	4112	542	559	646	7008
2754	44	414	544	562	648	7034
2782	442	4166	546	565	65	706
281	444	4192	548	568	652	7086
2834	446	4218	55	571	654	7112
2858	448	4244	552	5738	656	7138
2882	45	427	554	5766	658	7164
2906	452	43	556	5794	66	719
293	454	433	558	5822	662	7214
2956	456	436	56	585	664	7238
2982	458	439	562	588	666	7262
3008	46	442	564	591	668	7286
3034	462	4448	566	594	67	731
306	464	4476	568	597	672	7334
3086	466	4504	57	6	674	7358
3112	468	4532	572	6024	676	7382
3138	47	456	574	6048	678	7406
3164	472	459	576	6072	68	743
319	474	462	578	6096	682	7454
3217	476	465	58	612	684	7478
3244	478	468	582	6148	686	7502
3271	48	471	584	6176	688	7526
3298	482	4738	586	6204	69	755
3325	484	4766	588	6232	692	7574
3352	486	4794	59	626	694	7598
3379	488	4822	592	6288	696	7622
3406	49	485	594	6316	698	7646
3433	492	488	596	6344	7	767
346	494	491	598	6372	702	7694
3488	496	494	6	64	704	7718
3516	498	497	602	6428	706	7742
3544	5	5	604	6456	708	7766
3572	502	503	606	6484	71	779
36	504	506	608	6512	712	7812
3624	506	509	61	654	714	7834
3648	508	512	612	6568	716	7856
3672	51	515	614	6596	718	7878
3696	512	5178	616	6624	72	79
372	514	5206	618	6652	722	7924
3748	516	5234	62	668	724	7948
3776	518	5262	622	6704	726	7972
3804	52	529	624	6728		

Ullage table for lying casks—contd

Quotient	Equivalent.	Quotient	Equivalent.	Quotient	Equivalent
728	7996	83	907	932	9808
73	802	832	9088	934	9818
732	8042	834	9106	936	9828
734	8064	836	9124	938	9838
736	8086	838	9142	94	9848
738	8108	84	916	942	9858
74	813	842	9178	944	9866
742	8152	844	9196	946	9874
744	8174	846	9214	948	9882
746	8196	848	9232	95	989
748	8218	85	925	952	9898
75	824	852	9268	954	9905
752	8262	854	9286	956	9911
754	8284	856	9304	958	9917
756	8306	858	9322	96	9923
758	8328	86	934	962	9928
76	835	862	9356	964	9932
762	8372	864	9372	966	9937
764	8394	866	9388	968	9941
766	8416	868	9404	97	9945
768	8438	87	942	972	99494
77	846	872	9434	974	99538
772	8482	874	9448	976	99582
774	8504	876	9462	978	99626
776	8526	878	9476	98	9967
778	8548	88	949	982	99716
78	857	882	9502	984	99762
782	8592	884	9514	986	99808
784	8614	886	9526	988	99854
786	8636	888	9538	99	999
788	8658	89	955	992	9992
79	868	892	9564	994	9994
792	87	894	9578	996	9996
794	872	896	9604	998	9998
796	874	898	9617		
798	876	9	963		
8	878	902	9642		
802	8802	904	9655		
804	8824	906	9668		
806	8846	908	9678		
808	8868	91	969		
81	889	912	9701		
812	8908	914	9712		
814	8926	916	9723		
816	8944	918	9734		
818	8962	92	9745		
82	898	922	9755		
822	8998	924	9765		
824	9016	926	9775		
826	9034	928	9786		
828	90[illegible]	93	9798		

APPENDIX VII.

Casking wastages.

At times slight losses of duty may occur through the absorption by the spirit of obscuring substances obtained from the cask Such substances usually are tannins of various kinds obtained from the wood and sugars absorbed from spirits previously stored in the cask But the errors due to the use formerly of the uncorrected Sikes's Tables and to faulty methods of reduction of spirits have caused the impression that losses from obscuration by casking may at times be very marked The use of the Corrected Sikes's Tables and of the Reduction Tables which will allow reduction to be carried out correctly, allowing for normal shrinkage, will tend to remove this idea

The subject of wastage from obscuration by casking was investigated at the Central Excise Laboratory and it was found that, although undoubtedly at times casking obscuration does occur, it is very slight and irregular in nature For example spirits casked for as much as 10 years showed no obscuration whatever The general rule is that spirits casked for periods up to 2 years show no obscuration from casking Spirits casked for longer than two years show no regular increase of obscuration The occurrence or otherwise of casking obscuration must necessarily vary considerably, as this depends on the kind of wood in which the spirit is stored, the previous age of the cask or vat, and the use to which it has been previously put (*e g*, whether a strongly coloured spirit has or has not been stored in it) No general rule can thus be laid down for the Excise officer s guidance as to obscuration from casking and no allowance can, therefore, be fixed Usually in India storage for only a few weeks is the rule in the case of country spirits, and obscuration from this cause is so small as to be negligible

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APPENDIX VIII.

Increase in strength of spirits on storage.

As regards spirit placed in wooden casks in such a manner that loss by direct evaporation is avoided, investigation at the Central Excise Laboratory has shown that

A In damp climates, the spirit strength remains either stationary or falls slightly, that is within periods of time such as were occupied by the experiments made This is in accordance with experience in the United Kingdom

where, in some very damp places, loss in bulk gallonage, i e, dryage, is quite small and is accompanied by an appreciable decrease in spirit strength

B In very dry climates, a distinct increase in spirit strength may normally occur In the case of spirit stored in large casks, this may amount to about 2 degrees proof in a period of 12 months At the same time an 18 per cent loss by dryage may take place, *e g*, 50 gallons were found to have lost 9 gallons in 12 months

In the case of small quantities of spirit of fairly high strength, say, 25° U P, which have been stored in wood, the increase may amount to 10° proof or over in the course of a year, especially where a large air space is present in the cask Under such circumstances, about half the bulk of the spirit may be lost by dryage It is thus evident that there can be no inducement to the trader to secure a gain in strength by keeping spirit under favourable conditions, as this is more than counterbalanced by dryage It may be further noted that the weaker spirits show less increase in strength than do the stronger types

C As regards spirits kept in jars, bottles or other non permeable vessels, whether in damp or dry climates, any change in strength is only in the direction of loss by evaporation

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APPENDIX IX.

Grogging Operations.

The Madras Board of Revenue have laid down the following instructions which have for their object the prevention of the possibility of weak liquor being obtained from empty casks which have contained liquor They apply only to warehouses and to distilleries which supply liquor to such warehouses and depôts, but not to casks that have contained duty paid liquor —

(1) All casks should be drained as completely as possible

(2) Before removal from the warehouse they should be "grogged" with water Into each cask five gallons of water should be put and, after being securely bunged down, the cask should be well rolled so as to bring the water in contact with the whole of the internal surface It should then be allowed to lie for at least two hours in one position, should then be again rolled and then placed in such a position for another period of two hours as to expose another portion of the surface to the action of the water This should be repeated at least three times so that the whole of the surface may have been subjected to the action of the water for two hours The weak liquor so obtained, which will, when the original liquor

was 40° overproof, probably be found to be about 80° underproof, can either be utilized in reduction of strong spirit, or, if preferred, can be destroyed by being poured out on the ground

(3) Until the operation is completed the casks should be kept under Excise lock Where there is insufficient storage room in the warehouse itself, another room must be provided in which they can be stored under Excise lock, but the actual operation of grogging must be performed in the warehouse itself

(4) A note should be made in the Cask Register as to when the casks were emptied and when grogged and how the weak spirit was disposed of

Superior officers on inspection should see that these provisions are being properly carried out and specially report any case in which they have been disregarded

Warehouse keepers will however be allowed to return empty casks to distilleries ungrogged under the following conditions —

(1) All empty casks must be kept under Excise lock either in the warehouses or in a place specially set apart for them until they are despatched They may be broken up into shooks* for transit or, if returned whole must be securely bunged down, the bungs being secured as in the case of full casks

(2) The officer in charge will intimate to the officer in charge of the distillery to which the casks are returned the numbers and marks of the casks, and the receiving officer will state in the letter of advice whether the casks were received with the seals unbroken Any indications that the bungs have been tampered with should be noted and specially reported by him

(3) A note should be made in the Cask Register against all casks despatched ungrogged, showing whether they were broken up into shooks or returned bunged down

(4) All casks received ungrogged at a distillery should be kept under lock until they are required for cooper's examination or for refilling A register showing the numbers of the casks and the date of their receipt into and issue from the empty cask store should be opened at all distilleries whence supplies are made to warehouses, or wholesale vend depôts

Water poured into empty liquor vats to prevent shrinkage of the wood, which becomes alcoholic by abstraction of the spirit absorbed by the wood, should either be destroyed in the presence of the officer in charge or issued for distillation at the option of the distiller, the fact of such destruction or distil-

* A shook is a set of staves sufficient to make one cask.

lation, as the case may be, being noted in the registers It may also be used in reduction without bringing it to account separately where its quantity is small compared with the bulk of stronger liquor to be reduced But in all such cases, the vats should be kept locked

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APPENDIX X.

Instructions for testing light caoutchoucine and pyridine bases to be used for denaturing alcohol.

1 —LIGHT CAOUTCHOUCINE

SPECIFICATION FOR LIGHT CAOUTCHOUCINE

(1) *Nature* —By " Caoutchoucine " is meant the liquid obtained by the dry distillation of vulcanized rubber By " Light Caoutchoucine " is meant the liquid obtained by redistilling " Caoutchoucine " and collecting that portion which passes over at or below about 200° C

(2) *Specific gravity of Light Caoutchoucine* —The specific gravity of light caoutchoucine at 60° F should lie between 835 and 860 referred to water as 1 000

(3) *Boiling test* —For the purpose of this test, 100 c c of light caoutchoucine should be redistilled in the pyridine testing flask (*see* specification for pyridine bases)

Under these conditions not more than 15 c c of distillate should pass over at or below 100° C, whilst a total (including the foregoing) of at least 70 c c should pass over at or below 200° C

(4) *Absence of soluble constituents* —When 25 c c of light caoutchoucine are shaken with an equal volume of water in a stoppered graduated cylinder and due time is allowed for the liquids to separate again into two layers, the light caoutchoucine should show no appreciable diminution in volume

(5) *Neutrality* —The aqueous layer obtained from test (4) should show no marked acidity or alkalinity when tested with both red and blue litmus paper

(6) *Limit of saturated hydrocarbons* —At least 70 per cent of the light caoutchoucine should be soluble in concentrated sulphuric acid For testing this 25 c c should be measured off into a tapped and stoppered separating-cylinder of suitable capacity, and sulphuric acid should be added, at first with great care and in very small quantities After each addition of acid, the cylinder should be shaken and cooled to avoid loss of volatile constituents Sufficient acid must be used (usually about 50 c c) for the highly coloured layer to become quite fluid so that it can separate readily from the upper

layer of unattacked constituents After a final thorough shaking and cooling, the cylinder should be left for about 3 hours to effect complete separation of the two layers and the lower layer be then tapped off The almost colourless upper layer should be again shaken with strong sulphuric acid until it appears free from soluble constituents (as judged by the colour imparted to the sulphuric acid) and separated as before after standing It should finally measure not more than 7 c c The acid used should be of specific gravity 1 84 and may be of commercial quality

(7) *Freedom from water* —Light caoutchoucine should not contain any appreciable amount of water Any officer engaged in drawing samples for test should certify on the bottle that he has drawn the sample from the bottom of the containing vessel where the water if present, will be found For this purpose he should employ a syphon tube of which the shorter limb reaches to the floor of the containing vessel He should also assure himself that the sample is collected in a bottle free of moisture

II —PYRIDINE BASES

Specification for Pyridine Bases

(1) *Nature* — Pyridine' proper is a single definite compound ($C^5 H^5 N$) *boiling at about* 116° C Pyridine bases *are mixtures of pyridine with* closely allied compounds boiling at various temperatures and must be of guaranteed mineral origin

2 *Colour* —The colour must not be darker than that given by two cubic cent metres of deci normal iodine solution dissolved in one litre of distilled water

3 *Miscibility with water* —20 c c of the pyridine bases should give a clear mixture with 40 c c of water or else a mixture only so slightly opalescent that after standing for five minutes ordinary newspaper type is clearly visible through a layer 15 c m deep

4 *Amount of water present* —From 20 c c of the pyridine bases mixed with 20 c c of caustic soda solution (density 1 4) at least 18 5 c c of the bases should separate after having been repeatedly shaken together and allowed to stand

5 *Titration* —Dissolve 1 c c of the pyridine bases in 10 c c of distilled water Titrate with normal sulphuric acid until a drop of the mixture gives a definite blue spot on congo red paper (the blue colour should at once disappear) At least 10 c c of the normal sulphuric acid should be required to produce this reaction To prepare the congo red paper dissolve one gram of congo red in one litre of distilled water Soak filter paper in this and then dry

6 *Cadmium chloride reaction* —Vigorously shake together 10 c c of a solution of 1 c c of pyridine bases in 100 c c of distilled water with 5 c c of a 5 per cent solution of dry fused cadmium chloride A distinct crystalline precipitate should immediately result

7 *Boiling point*—Distil 100 c c of the pyridine bases in the manner described below At least 90 per cent should distil over at or under 140 degrees C

Method—100 c c of pyridine bases are placed in a short-necked copper flask of about 200 c c capacity The flask is arranged on an asbestos card which has a circular hole of 30 m m diameter cut in it To the flask is attached a fractionating column (consisting of a tube 13 m m wide and 170 m m long, provided with one bulb) of which the side tube (issuing 1 c m above the bulb) joins a Liebig s condenser of which the cooled part is at least 400 m m long * A standard thermometer is placed in the head of the column so that its bulb occupies the centre of the bulb of the column

The speed of distillation is adjusted to 5 c c per minute, the distillate being received in a graduated glass cylinder At least 90 c c should distil over at or under 140° C at a barometric pressure of 760 m m

If the barometer varies from 760 m m , a correction of 1° C for each 30 m m of variation should be applied (*e g* , under 770 m m of pressure 90 c c of distillate should come over at or under 140 3° C , whilst under 750 m m the same amount of distillate should come over at 139 7° C)

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